Law of the Sea

• Treaties regarding ownership and exploitation of the marine resources ratified during the last 50 years
  – Truman extended U.S. control of the marine resources from the shoreline to a depth of 100 fathoms
  – 1958 and 1960 Geneva Conventions on the Law of the Sea resulted in a treaty that placed the control of the sea bed, sea bed resources, and waters of the continental shelf under the country that owns the nearest land

• Territorial waters extend seaward for 12 nautical miles from the coast and are under direct jurisdiction

• An exclusive economic zone (EEZ) that extends for 200 nautical miles offshore or to the edge of the continental shelf (if that is farther), giving nations the right to regulate fishing, mineral resources, pollution and research

• The right of vessels to free and innocent passage outside of the territorial waters and through international straits that lie within territorial waters

• That all private exploitation of mineral resources beyond the EEZ’s must be approved by the U.N. International Seabed Authority and that part of the revenue from the resources will be shared with the developing nations
EEZ

- The U.S. has the world’s largest EEZ because of the large areas surrounding various island possessions and states
- The U.S.’s EEZ is 30% larger than the land area of the U.S.
Exclusive Economic Zones (EEZ)
U.S. EEZ
Mineral Resources

- Petroleum, Oil, and Gas
- Gas Hydrates
- Sand and Gravel
- Manganese Nodules
- Cobalt Deposits
- Phosphorus
Petroleum

• Complex mixture of hydrocarbons
  – Hydrocarbon = combination of hydrogen and carbon with various amounts of nitrogen and metals

• Oil as it comes from the ground is called petroleum or crude oil
  – Composition varies greatly depending on the geologic history
  – Smaller hydrocarbons are less dense and lighter
  – Oil can be separated into various densities by distillation because oils of different densities evaporate at different temperatures
Petroleum, Oil and Gas

- Hydrocarbons derived from sedimentary rocks, which were deposited in quiet, productive regions with anoxic bottom waters in which the remains of phytoplankton accumulated

- Deep burial resulting in high temperature and pressure converted the organic remains to hydrocarbons
  - Initially oil, but higher temperatures and pressure, methane is generated

- Pressure forced the oil and gas from the source rock into water-filled porous and permeable strata above

- Oil and gas accumulated, forming a large deposit – usually sandstone
Oil and Gas Deposits
How oil is found

• Location of possible accumulations of oil and gas can be determined using seismic reflection and refraction methods to determine the configuration of rock layers

• This only indicates the potential to trap oil and gas, not if oil and/or gas is present

• Large reserves in ANWR and Mars in Gulf of Mexico (but small compared to U.S. consumption)
Gas Hydrates

- Unusual hydrocarbon deposits that consist of frozen water molecules entrapping a single methane molecule
- Occur in polar sediments and in deposits of the continental slope between the depths of 300 and 500 m where cold water is in contact with the sea floor
- Deposits contain incredibly large amounts of gas, but no economical method for its recovery at present
- North Carolina deposits – 350 x annual energy consumption of the U.S. (6.6 billion barrels/yr)
Sand and Gravel

- Natural aggregates of unconsolidated sediment with grain size greater than 0.065 mm in diameter
- Sand and gravel accumulate in high energy environments where strong currents and/or waves prevail
- Relict sediments on continental shelf from when sea level was lower
- Materials used for construction of roads and building
- Materials used to replenish beaches
- Mining sand and gravel threatens both the benthic and pelagic communities and introduces large amounts of material into suspension
- Only 1% of sand and gravel presently taken from offshore
Sand and Gravel
Manganese Nodules

• Composed of about 20-30% manganese, 10-20% iron oxide, 1.5% nickel, and less than 1% copper, zinc and lead
• Locally the nodules are very abundant
• Presently, no economical method of recovering them from the deep sea
Cobalt Deposits

• Sides of many seamounts and islands are enriched in cobalt between the depths of 1000-2500 m
• Cobalt is a strategic metal used in making jet engines
• U.S. cannot produce sufficient cobalt to meet its needs
Phosphorus

- Phosphorus is required for growth by all organisms
- Phosphate deposited generally form on submarine terraces where coastal upwelling generates high productivity
- Organic wastes and remains accumulate in the sediment and as they decay they release phosphorus compounds, which precipitate as phosphate nodules
- Nodules grow at the rate of about 1-20 mm/1000 yr
- World consumption of phosphate is about 150 million tons/yr
- Known supplies should last until 2050
Living Resources

• Fishing
• Whaling
• Mariculture
Fishing

- Two types of fish are fished
  - Pelagic – live in water column
  - Groundfish – live on sea floor
Fishing

• Most of the ocean is sparsely populated because of low nutrient availability
• Major fish production areas are coastal waters and regions of upwelling
• Because they are economic to capture, major commercial fishes are those which form large schools
Fishing Methods

• To locate the fish
  – Sonar
  – Scouting vessels
  – Airplanes
  – Satellites

• Nets
Drift Nets

- Controversial, because they capture everything too large for the net and needlessly kill many organisms
- 1989 U.N. Convention for the Prohibition of Long Drift nets prohibits drift nets longer than 2.5 km
  - Compliance is voluntary
  - Impossible to enforce
Fishing Sustainability

• World ocean fish production appears to have leveled at between 80-100 million tons/yr

• Maximum sustainable catch estimated to be 100 million tons/yr

• Currently the expense to fish exceeds the profit from the sale of fish
  – Fishing industries survive only through government subsidy
Overfishing

• Removing a living resource from the sea faster than it can replace itself

• If continued long enough, the resource will collapse

• Overfishing is possible today
  – Technology has made it easier to locate large schools of fish and to direct fishing fleets to those locations
  – Mismanagement of policies related to sustaining fish populations
  – Fishermen resist quotas and misreport catches
Fishing Harvests

(a) PERUVIAN ANCHOVY

(b) SARDINE

(c) PACIFIC HERRING AND JAPANESE MACKEREL

**Figure 15-17** Declining harvests. Decline in total fish catch for (a) Peruvian anchovy, (b) sardine, (c) Pacific herring and Japanese mackerel. [Adapted from M. Berrill, The Plundered Sea: Can the World's Fish Be Saved? (San Francisco, Calif. Sierra Club Books, 1997).]
Maximum Sustainable Yield

• Theoretical maximum amount of fish that can be removed from a population without significantly interfering with the population’s ability to renew itself
• Based on biological factors such as population dynamics, food webs, and spawning success, and the fishing effort required to produce a given catch
Problems with determining a maximum sustainable yield

- Under-reporting the amount of fish caught
- Natural fluctuations of populations due to predation and food supply
- The inherent difficulty in determining the size of fish populations
- The unknown impact of discard fish (those returned to the sea because they are too small or of poor quality) on the population
- Politics frequently result in altering the scientifically determined maximum sustainable yields to meet political ends
- Should be replaced by precautionary principle, which is to avoid anything which may damage or negatively impact a fishery
Mariculture

• Marine agriculture or fish farming
• Finfish, shell fish, or algae
• Currently, about ¼ of the fish consumed has spent part of its life in mariculture
• For some species, this percentage is higher
• For mariculture to be economically viable, the species must be
  – Marketable
  – Inexpensive to grow
  – Trophically efficient
  – At marketable size within 1 to 2 years
  – Disease resistant
Mariculture vs. Fishing

![Graph showing the increase in fish catch and mariculture over the years from 1950 to 2000.](image)
The Human Presence in the Ocean

- Pollution
- Hydrocarbons – natural and spills
- Municipal and Industrial Wastes
- Ocean Dredging and Mining
Pollution

- Introduction by man, directly or indirectly, of substances of energy into the environment, resulting in deleterious effects such as harm to living resources, hazards to human health, hindrance of marine activities, including fishing, impairing quality for use of sea water and reduction of amenities
## Pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Natural Source</th>
<th>Human Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons</td>
<td>Seeps, rivers, volcanoes, atmosphere, bacteria</td>
<td>Transportation, production, aerosols</td>
</tr>
<tr>
<td>Heavy Metals</td>
<td>Volcanoes, rivers, sediments, weathering of rocks</td>
<td>Industrial and municipal effluents</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Rivers, upwelling, atmosphere, bacterial decomposition</td>
<td>Municipal effluents, agricultural fertilizers</td>
</tr>
<tr>
<td>Synthetic Chemicals</td>
<td>None</td>
<td>Manufacturing, transportation, agricultural fertilizers, and pesticides</td>
</tr>
</tbody>
</table>
Extent of Pollution
Studying Pollution

• Need to have a baseline from which to measure man’s impact upon the environment, because some of what is considered to be pollution may be occurring naturally and not caused by man

• Pollutants are eventually broken down by various oceanographic and biological processes
Parts of the ocean where pollution is concentrated

• Sea floor – bottom of ocean
  – Accumulation on bottom by settling or by becoming attached to particles which settle
  – Mainly affects benthos

• Pycnocline – density gradient between surface and deep ocean
  – Accumulation because pollutants are too light to sink through dense bottom layer
  – Often occurs in estuaries

• Neuston layer – air-water interface
  – Mainly affects plankton
Hydrocarbons

• Only a small fraction of the oil in the sea comes from major oil tanker accidents
  – 31% from contaminated rivers
  – 32% from tanker release as they pump their bilges, incomplete burning of fuel, and general ship traffic
  – 13% from leakage at coastal refineries
  – 20% from natural oil seeps and atmospheric fallout

| Source: Adapted from R. A. Geyer, ed. Marine Environmental Pollution, 1 |
Transportation Routes for Crude Oil
Hydrocarbon Fates

• Altered in the environment
  – Spreading
    • Lighter than water so it floats
    • Spreads to be film on top
  – Drift by currents and wind
  – Evaporation
    • Light portion evaporates
  – Dissolution
    • Soluble portion dissolves
  – Emulsification
    • Heavy portion
    • Forms into a water-oil mixture without dissolving
    • Globules which eventually form tar balls, which wash ashore or sink
  – Sedimentation
    • Attaches to particles and sinks to bottom
  – Biodegradation
    • Broken down into CO₂ by bacteria
    • Some ingested by larger organisms
Hydrocarbon Fates

[Diagram showing various processes related to hydrocarbon fate including evaporation, wind spray, atmospheric oxidation, rain and fallout, spreading, drift, water-in-oil emulsion, tar balls, carbon cycle, advection and diffusion, heavy oil residue, adsorption to particles, sedimentation, degradation or assimilation by benthos, mixing into sediment by burrowers, chemical breakdown, bacterial degradation, assimilation by plants, and time scale with events such as spreading, drift, evaporation, emulsification, sedimentation, and biodegradation.]
Methods to Clean an Oil Spill

• Floating booms
  – Barriers places around the spill to contain it
  – Not effective if waves are large or winds or currents are strong

• Chemical dispersants
  – Disperse the oil into the water
  – Do not remove the oil
  – Are often as damaging as the spill

• Burning
  – Difficult to ignite and keep burning
  – Causes air pollution

• Skimming

• Bioremediation
  – Stimulating growth of microbes that feed on oil and decompose it

• Oil which reaches shore, should be removed without disturbing the substrate
Municipal and Industrial Effluents

• Humans produce over 20 billion tons of wastes each year
• Much of that is disposed of in the ocean
• Most wastes from farmland, cities, and industrial areas
• Most wastes enter ocean through rivers
• All bodies of water have a natural capacity to clean themselves of a certain amount of pollution
• Dense populations can overwhelm that
Pollution Distribution
Pollutant Fates

- Diluted as it enters the ocean dependent on waves and currents
- Pollutant behavior depends on temperature, density, and stability
- A contaminant plume is formed upon release
- Plume increases in size with distance as the pollutant is diluter
Pollutant Fates

- Particulate matter will settle out, larger particles settle out first and closest.
- Some material will concentrate at pycnocline.
- Influence of pollution decreases with distance from the source.
Biota Distribution near Outfall

• At the source
  – the bottom will consist of sludge
  – No infauna

• Farther from the source
  – Dwarfed individuals

• At even greater distance
  – Fauna will be unusually abundant due to large amounts of nutrients
  – Fauna forms dense masses

• At a great distance
  – Fauna unaffected by the pollution
  – Normal density and normal size of individuals
Municipal and Industrial Wastes

• Sewage
  – Messy sludge of organic and inorganic compounds

• Heavy metals
  – Elements such as lead, mercury, cadmium, arsenic, and copper that normally occur in trace amounts but become toxic in larger dosages

• Artificial biocides
  – Man-made toxic chemical compounds that do not occur naturally
Bioaccumulation and Biomagnification

• Bioaccumulation
  – The process whereby organisms retain and concentrate a toxic material within their body

• Biomagnification
  – The process whereby a toxic material increases in concentration with each trophic level of a food chain
  – Results from bioaccumulation at each trophic level
Sewage

• Human waste is a major component of sewage
  – Organic matter
  – Inorganic nutrients (nitrates and phosphates)
  – Pathogens
    • Disease-causing organisms such as bacteria, viruses and parasites
Results of Sewage

- If sufficient nutrients are released, a phytoplankton bloom can occur
  - As dead phytoplankton sink to the bottom and decompose, an excessive demand on oxygen occurs
    - Biological oxygen demand (BOD)
    - Water becomes hypoxic or anoxic
    - Process called eutrophication
- Resulting low oxygen content will kill most organisms on the bottom and in the affected water column
  - As herbivores are killed, there is less grazing
  - More phytoplankton survive to reproduce and generate an even greater BOD
  - Eventually the food chain can be decimated
- Eutrophication observed in lakes, embayments, and even on sections of the continental shelf
Heavy Metals

• Normally added to the ocean in small amounts through the weathering of rocks and volcanic activity

• Manufacturing and industrial processes greatly increase the amount of heavy metals released

• Mercury, especially methyl mercury, is highly toxic because it is not biodegradable
  – Stored in the fatty tissues
  – Damages the central nervous system
… and fishing
Narragansett Bay

Hypoxic and anoxic conditions

Nickel concentrations in Narragansett Bay, Rhode Island. (a) A satellite image of Narragansett Bay. (b) The dramatic increase in the nickel concentration of the waters of Narragansett Bay with increasing distance from the estuary indicates the source of the metal is at the head of the bay. (c) The upper reaches of Narragansett Bay have received an ever-increasing load of nutrients from the surrounding land. This has led to eutrophication of the water and the creation of hypoxic and anoxic conditions. [Adapted from S. W. Nixon, Oceanus 36 (2) (1993): 38–47.]
Artificial Biocides

• Halogenated hydrocarbons or organochlorines are common
  – DDT
  – PCB
• Not biodegradable
• Remain for a long time
DDT

• Highly toxic
• Banned in most of the western world
• Use continues in some countries
• Sprayed on crops and soil, much washes into rivers
• Some remains airborne contaminating rain and snow or settling into the ocean
• Has been detected in the muds of the deep ocean and in the ice of Antarctica
• Large lens off Los Angeles
  – Miles in diameter, > 1 m thick
PCB

- Used in production of electrical equipment, paints, and adhesives
- Released into the environment by incineration and unregulated disposal
- Have been found throughout the ocean environment
- Hudson contaminated by GE
Agricultural Wastes

• Fertilizers and animal wastes washed off fields into rivers
• Eventually flow into ocean
• Act as fertilizer in ocean
• Cause eutrophication
Ocean Dredging
Ocean Dredging

- 80-90% of the material dumped at sea each year comes from dredging
- If dredged material is clean, it is less of a problem
  - If material is dumped slowly, many benthic organisms can work their way to the surface through the new layer of sediment
  - If material is dumped too rapidly, they are buried and killed
  - If the material is different than the original, a different group of organisms may colonize the area
  - Clean dredgings can be used to replenish beaches
Contaminated Dredge Sediments

- Represent an initial and long-term source of pollutants
- Come from harbors and rivers,
- Dredging the contaminated sediments reintroduces pollution into the water at the site of the dredging
- Dumping the sediment releases pollution at the dumping site
- As the dumped sediment compacts, contaminated pore water escapes and contaminates the water column
- Storms and currents disturb the sediment and reintroduce pollution
- To minimize reintroduction, contaminated sediment is frequently capped
Ocean Mining

• Mining will most likely be accomplished with a hydraulic pumping system that will vacuum water, sediment and organisms from the sea floor and bring them to the surface

• Most of these organisms will die

• Large areas of the sea floor will be disrupted and stripped of life

• Sediment released at the surface will create a massive sediment plume
  – If it remains suspended, it will reduce photosynthesis due to lower light from the increased turbidity
  – Rapid sinking could bury organisms
Name the 5 oceans