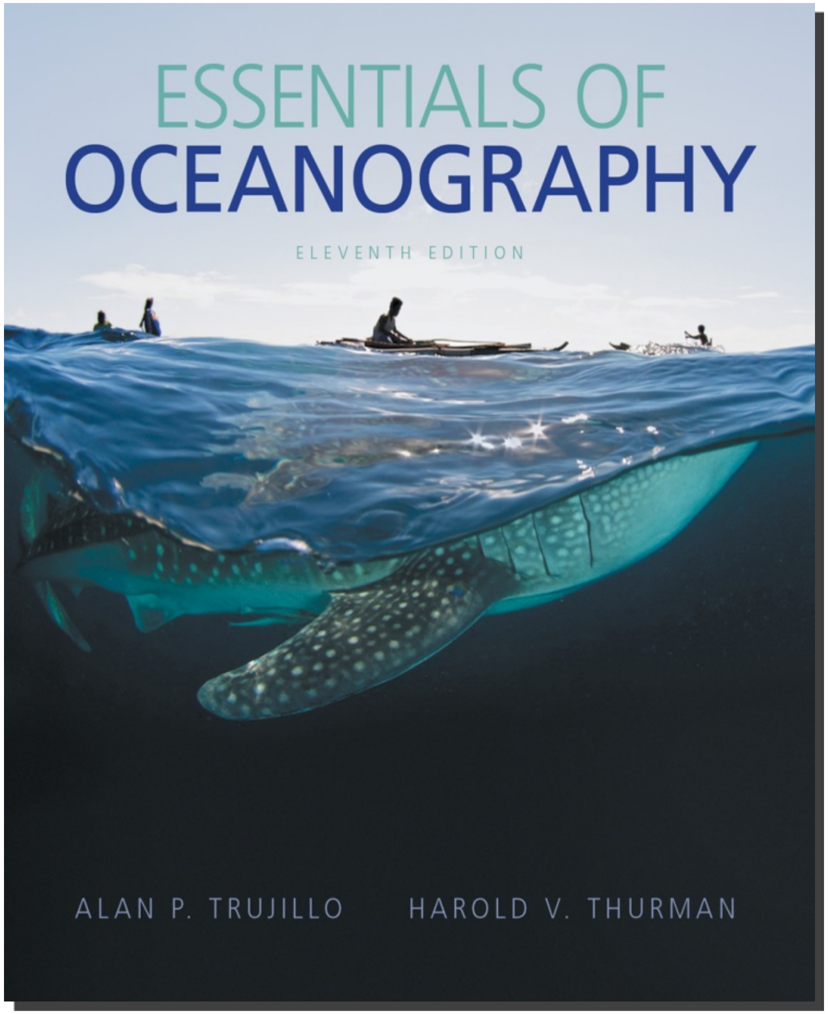
Essentials of Oceanography

Eleventh Edition



The Coastal Ocean

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Chapter Overview

- Various international laws govern ocean ownership.
- Coastal waters vary in characteristics.
- Coastal wetlands face environmental issues.
- Pollution is a major issue in the ocean.

Coastal Ocean

- 95% of world fishery obtained within 320 km (200 mi) of shore
- 95% ocean life mass in coastal waters
- Nursery grounds for many species
- Land compound conduit to open ocean
- Stressed by human activities

Ocean Ownership

- In 1609 the sea was free to all (*mare liberum*).
  - Assumed fish resources are inexhaustible
- Territorial sea – In 1702 the territorial sea area was declared under the coastal nation's sovereignty (3 nautical miles from shore).
  - Distance of cannon shot

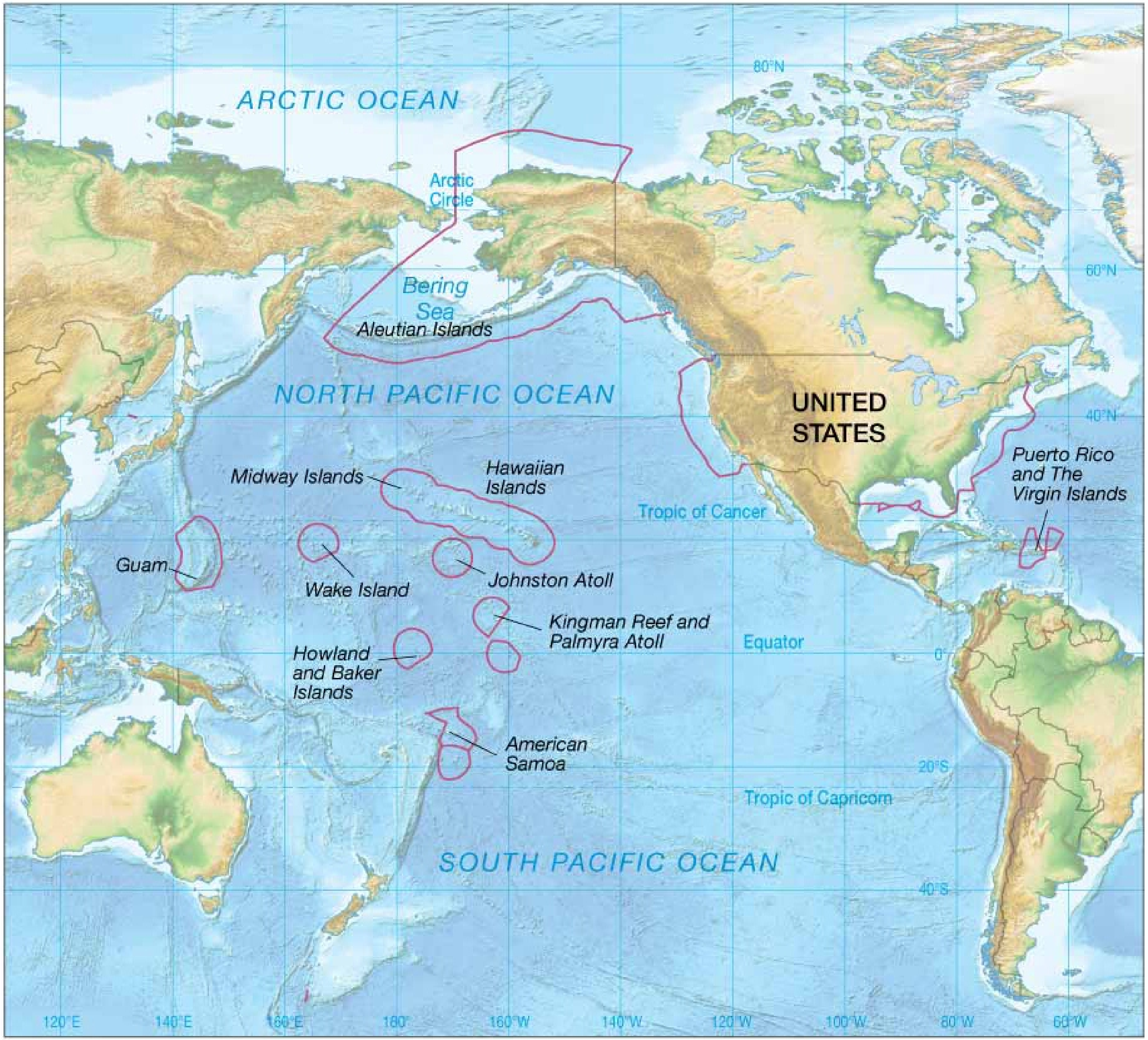
United Nations Law of Sea

- United Nations Conference on the Law of the Sea
  - 1958
  - 1960
  - 1973–1982
- Treaties have undergone revisions.

Law of the Sea

- Coastal nations jurisdiction
  - National sovereignty extends 12 nautical miles.
  - Exclusive Economic Zone (EEZ) 200 nautical miles (370 km) from land (mineral and fishing resources)
- Right of free passage for ships
- Open ocean mineral resources regulated by International Seabed Authority
- United Nations arbitrates disputes.

United States EEZ



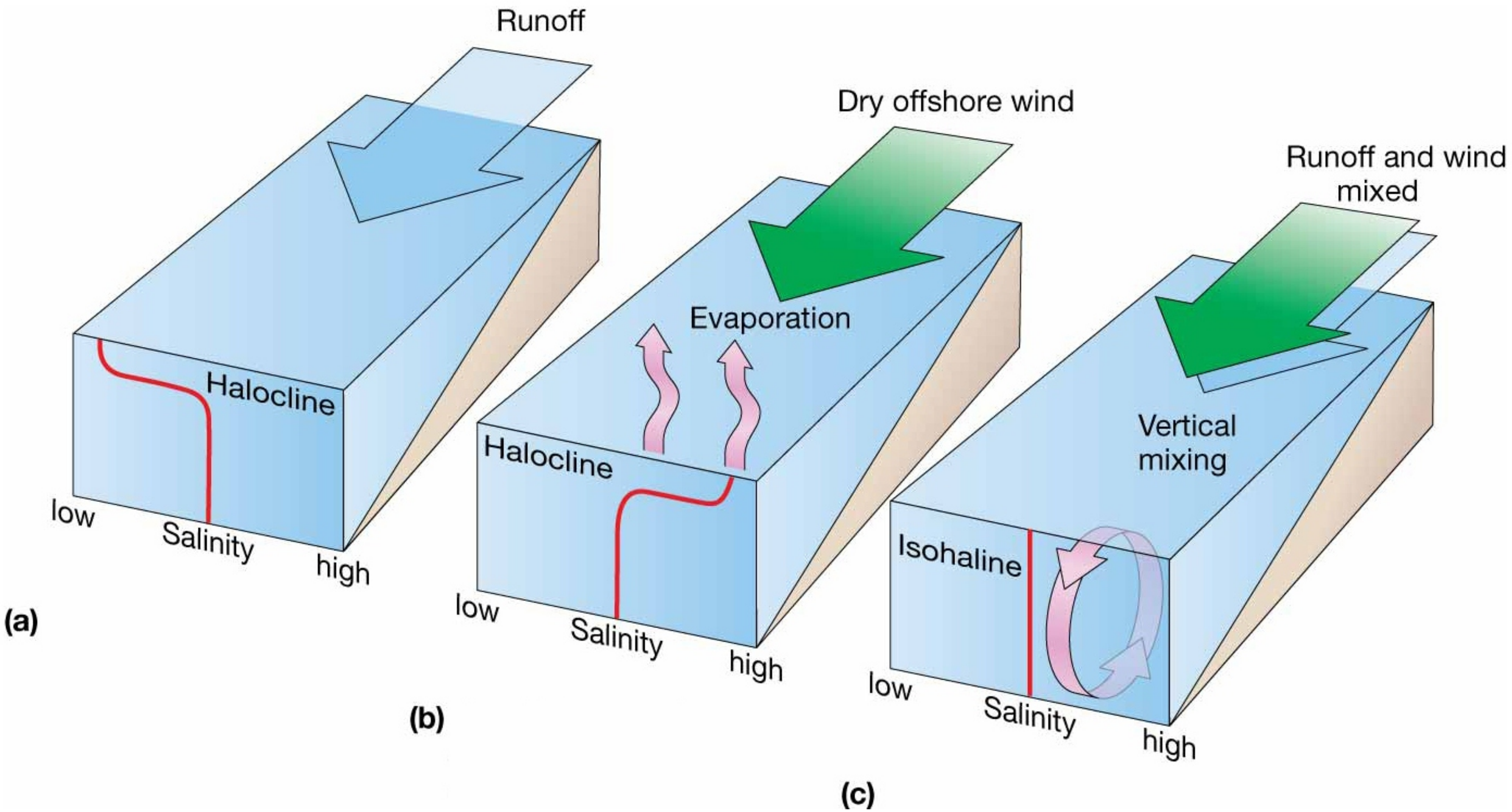
Characteristics of Coastal Waters

- Coastal waters
  – Relatively shallow
  – Adjoin continents or islands to edge of continental shelf
  – Influenced by river runoff, wind, tides
- Open ocean lies beyond coastal waters

Characteristics of Coastal Waters

- Salinity variable due to
  - Freshwater runoff
    - Can produce well-defined halocline
  - Winds
  - Mixing by tides
    - Water may be isohaline

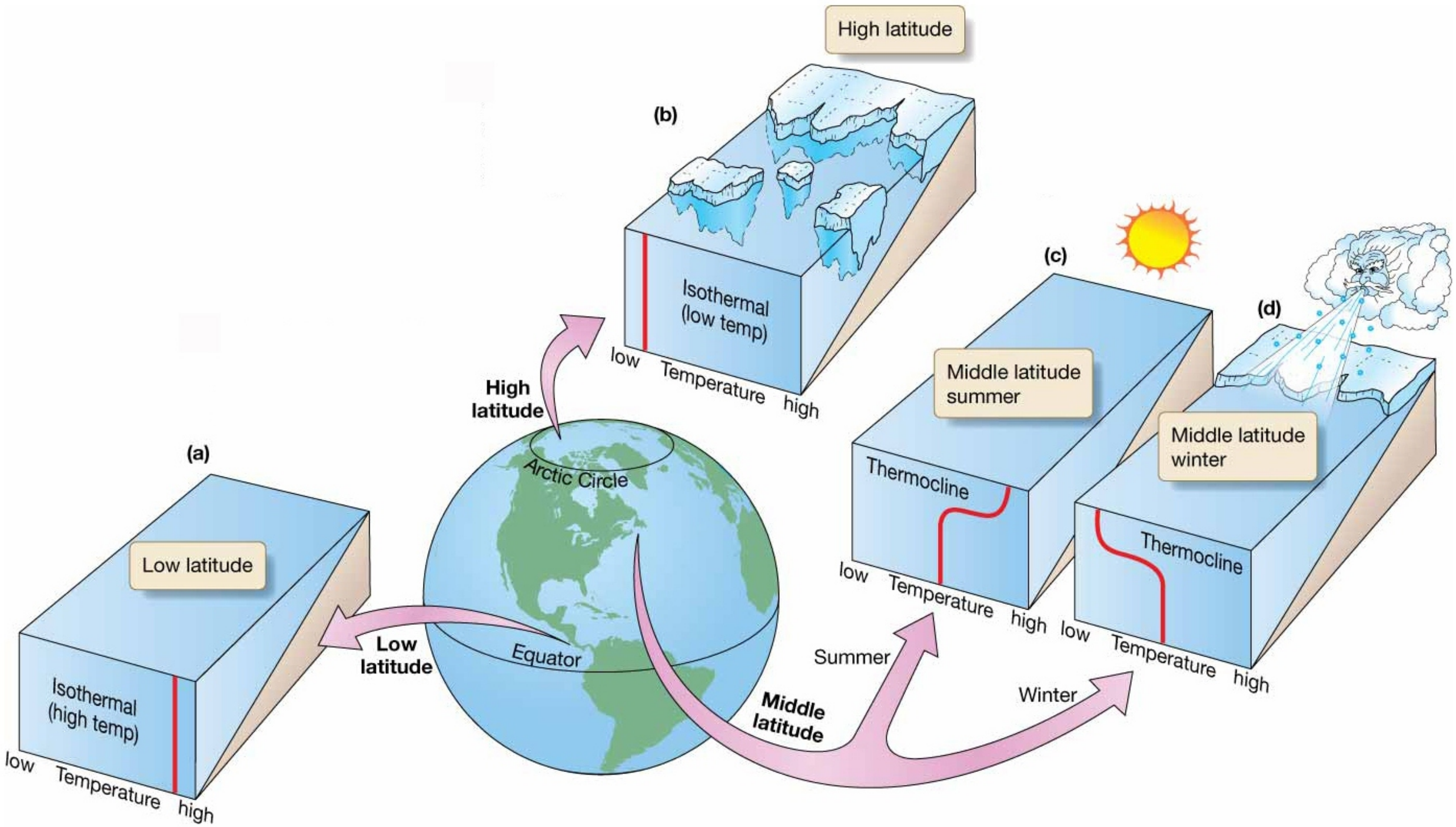
Salinity Variation in Coastal Ocean



Characteristics of Coastal Waters

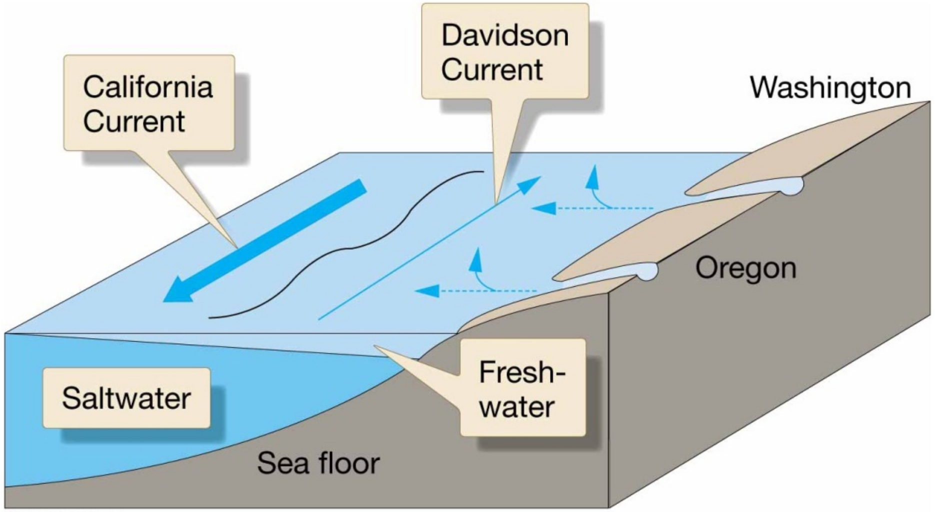
- Temperature variable
  - Low-latitudes – restricted circulation, very warm
  - High-latitudes – sea ice
    - Water may be isothermal at low and high latitudes.
  - Seasonal changes
  - Prevailing winds
  - A strong thermocline may develop at middle latitudes.

Temperature Variation in Coastal Ocean



Coastal Geostrophic Currents

- Wind and runoff
- Piled-up surface water affected by Coriolis effect and friction
- Flow parallel to coast
  - Davidson Current develops during winter along Washington and Oregon coast



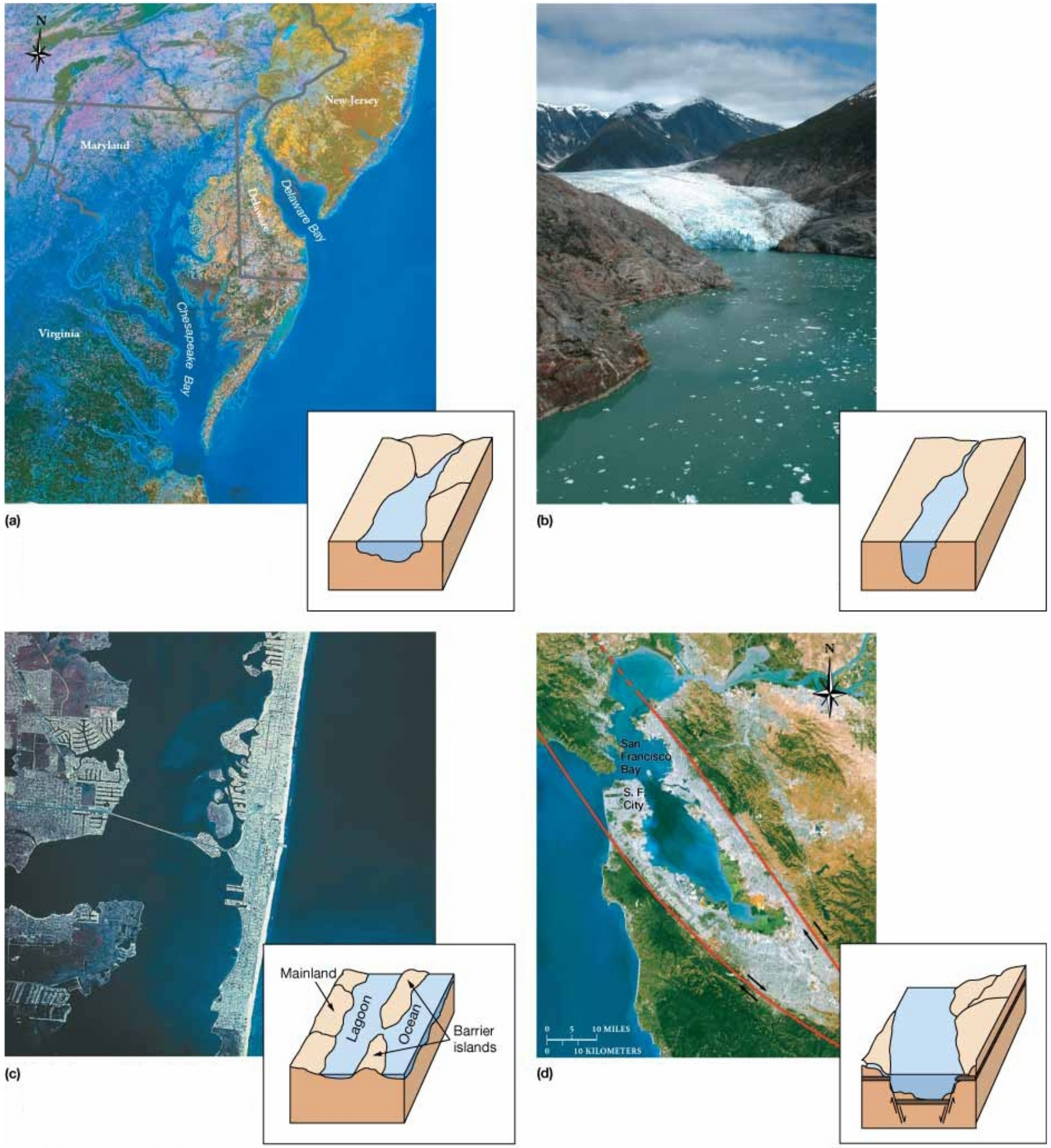
Types of Coastal Waters

- Estuaries
  - Partly enclosed body of water
  - Freshwater runoff dilutes ocean water.

Types of Estuaries by Geologic Setting

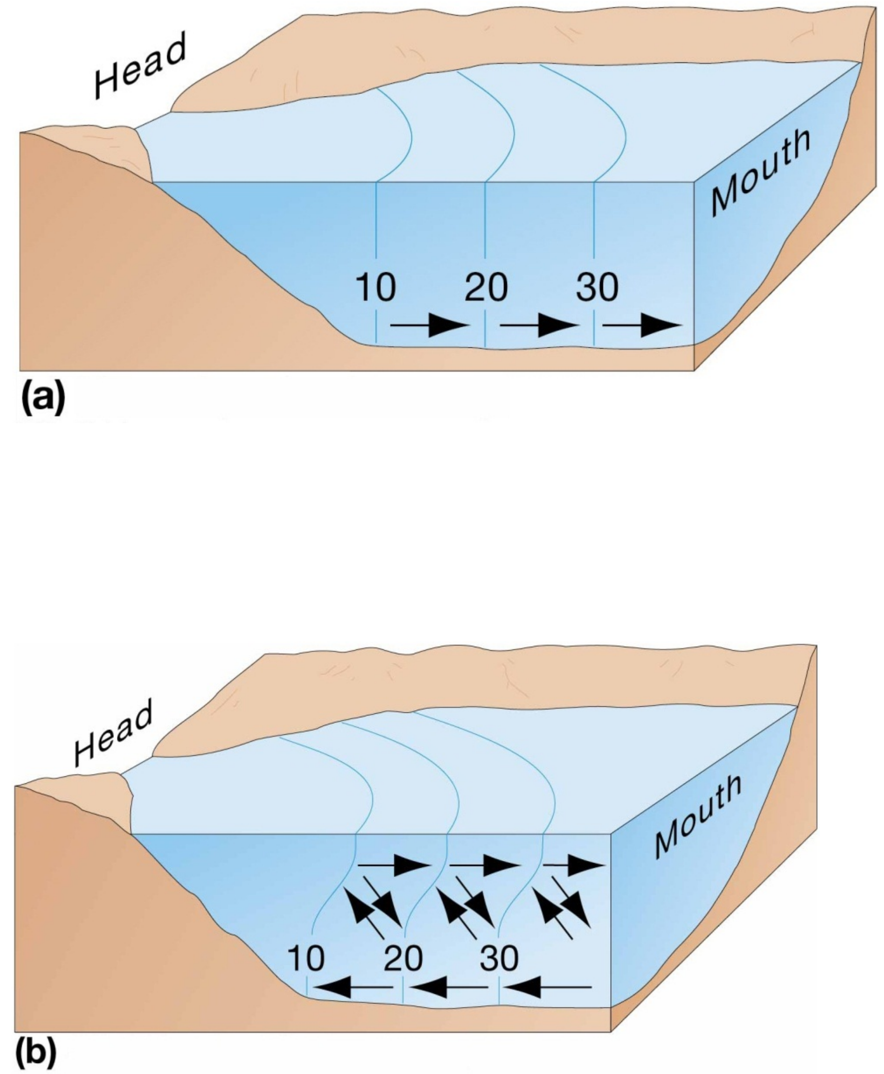
- Coastal plain estuary
  - Former river valley now flooded with seawater
- Fjord
  - Former glaciated valley now flooded with seawater
- Bar-built estuary
  - Lagoon separated from ocean by sand bar or barrier island
- Tectonic estuary
  - Faulted or folded downdropped area now flooded with ocean

Types of Estuaries by Geologic Setting



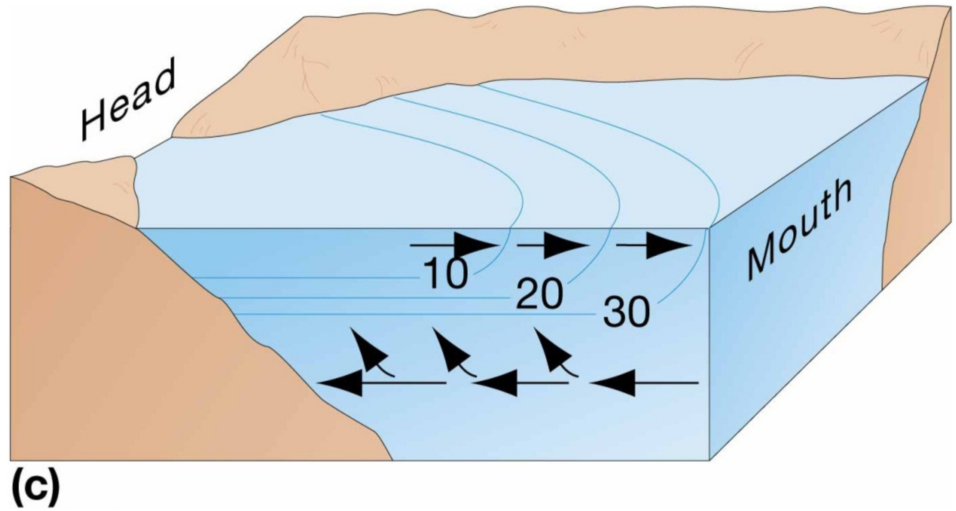
Water Mixing in Estuaries

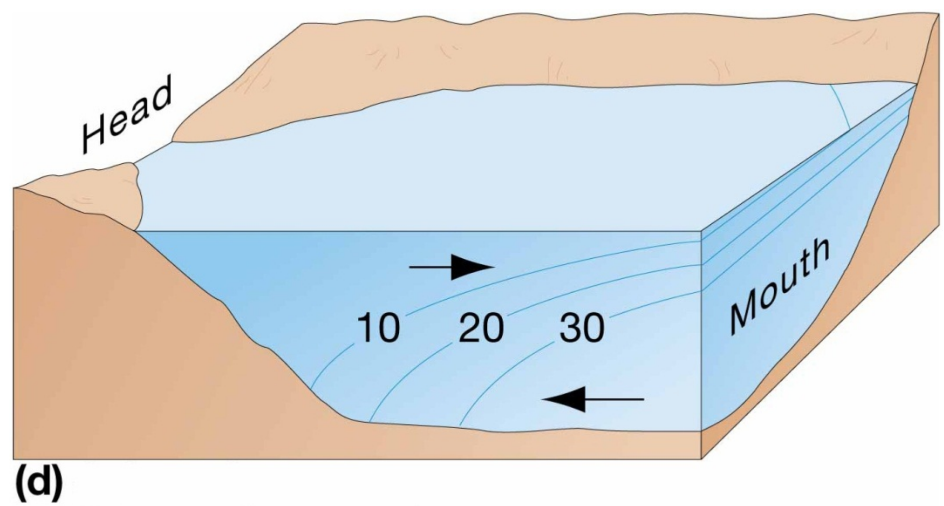
- Vertically mixed
  - Shallow, low volume
- Slightly stratified
  - Deeper
  - Upper layer less salty; lower layer more salty
  - Estuarine circulation



Water Mixing in Estuaries

- Highly stratified
  - Deep, relatively strong halocline
- Salt wedge
  - Deep, high volume
  - Strong halocline





Estuaries and Human Activities

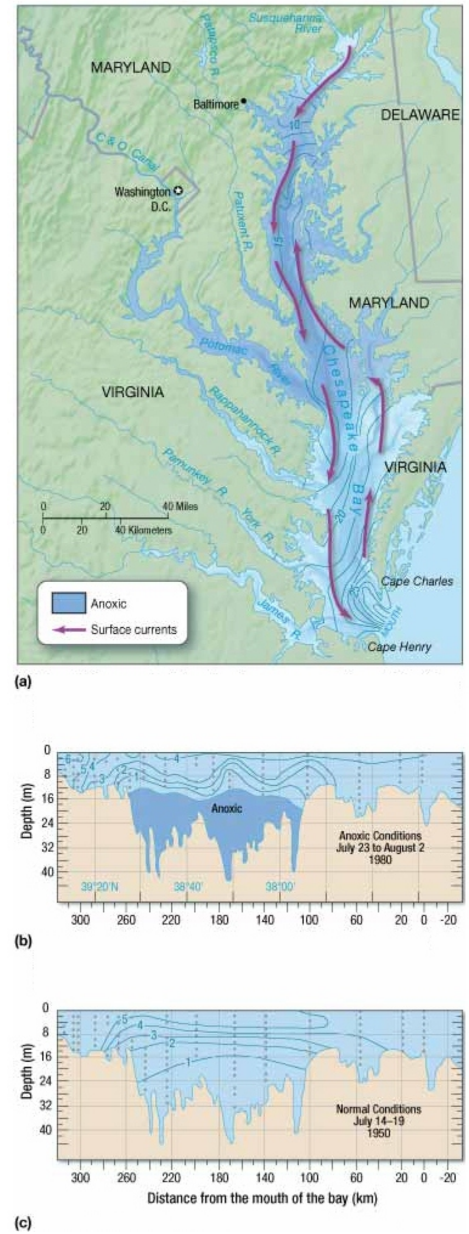
- Important breeding grounds for many marine animals
- Protective nurseries
- Pressures from increasing human populations

Columbia River Estuary

- Salt wedge estuary
- Damage done by flooding of agricultural areas
- Multiple dams have altered ecosystem
  - Example: No salmon ladders
- Logging industry damage

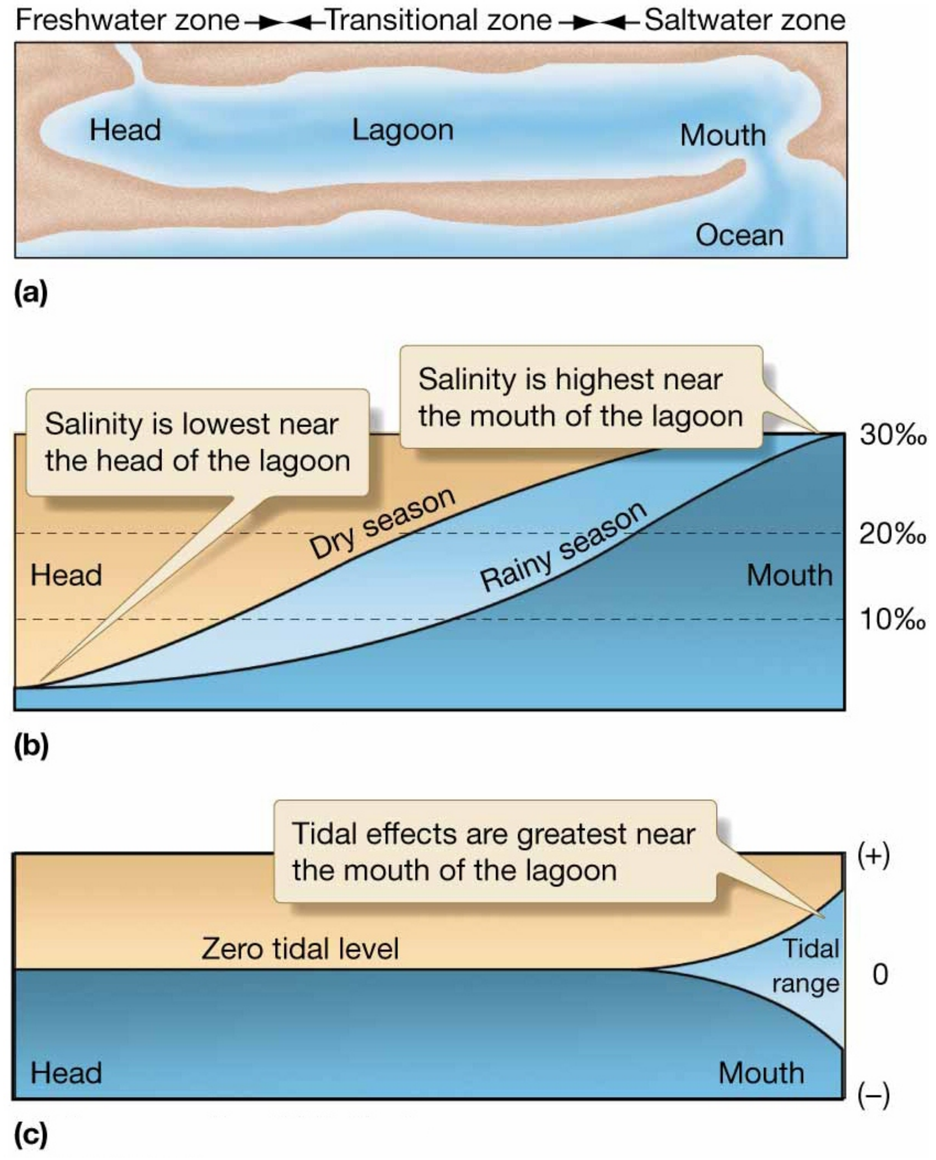
Chesapeake Bay Estuary

- Slightly stratified
- Seasonal changes in salinity, temperature, dissolved oxygen
- Anoxic conditions below pycnocline in summer – lack of oxygen
- Major kills of commercially important marine animals



Lagoons

- Protected, shallow water bodies landward of barrier islands
  - Freshwater zone
  - Transition zone of brackish water
  - Saltwater zone
  - Hypersaline in arid regions

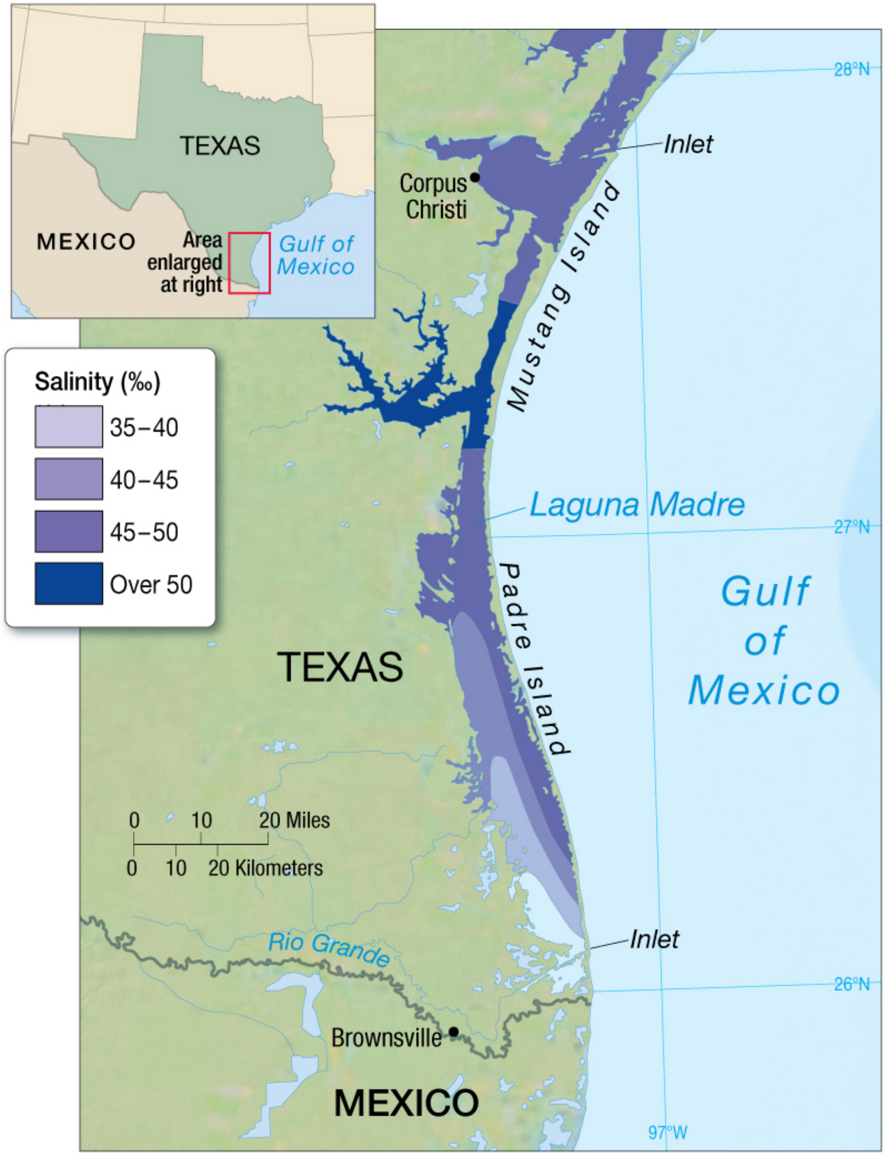


Lagoons

- Salinity highest near entrance and lowest near head
- Tidal effects greatest near lagoon entrance and diminish inland

Lagoons

- Laguna Madre along Texas coast formed about 6000 years ago
- Large temperature range
- Hypersaline
  - High evaporation
- Marsh replaced by open beach sand on Padre Island

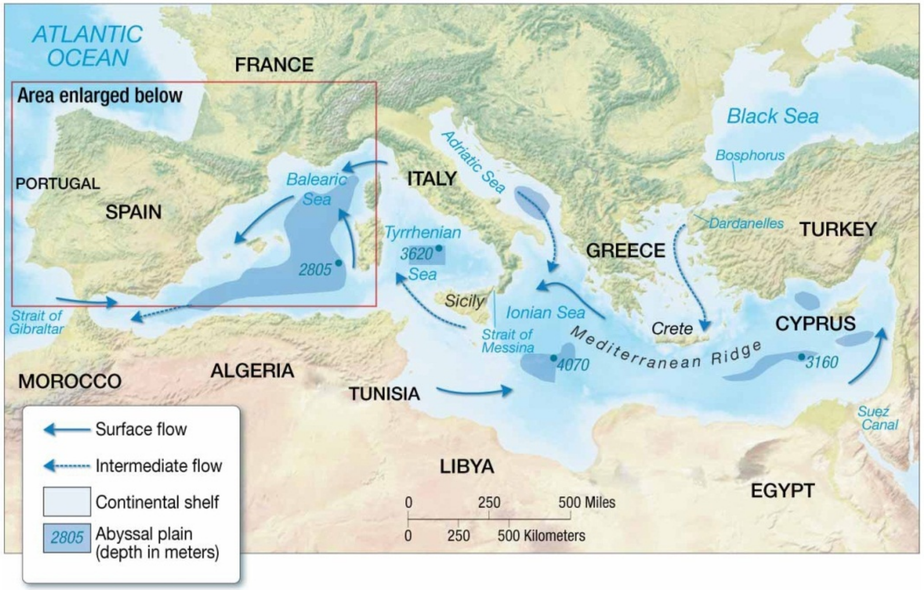


Marginal Seas

- Semi-isolated, mostly from tectonic events
  - Ocean crust between continents, e.g., Mediterranean Sea
  - Behind volcanic island arcs, e.g., Caribbean Sea
- Shallower than ocean
- Connected to ocean

Mediterranean Sea

- Remnant of Tethys Sea from 200 million years ago
- Deeper than usual marginal sea
- Underlain by oceanic crust
- Thick salt deposits



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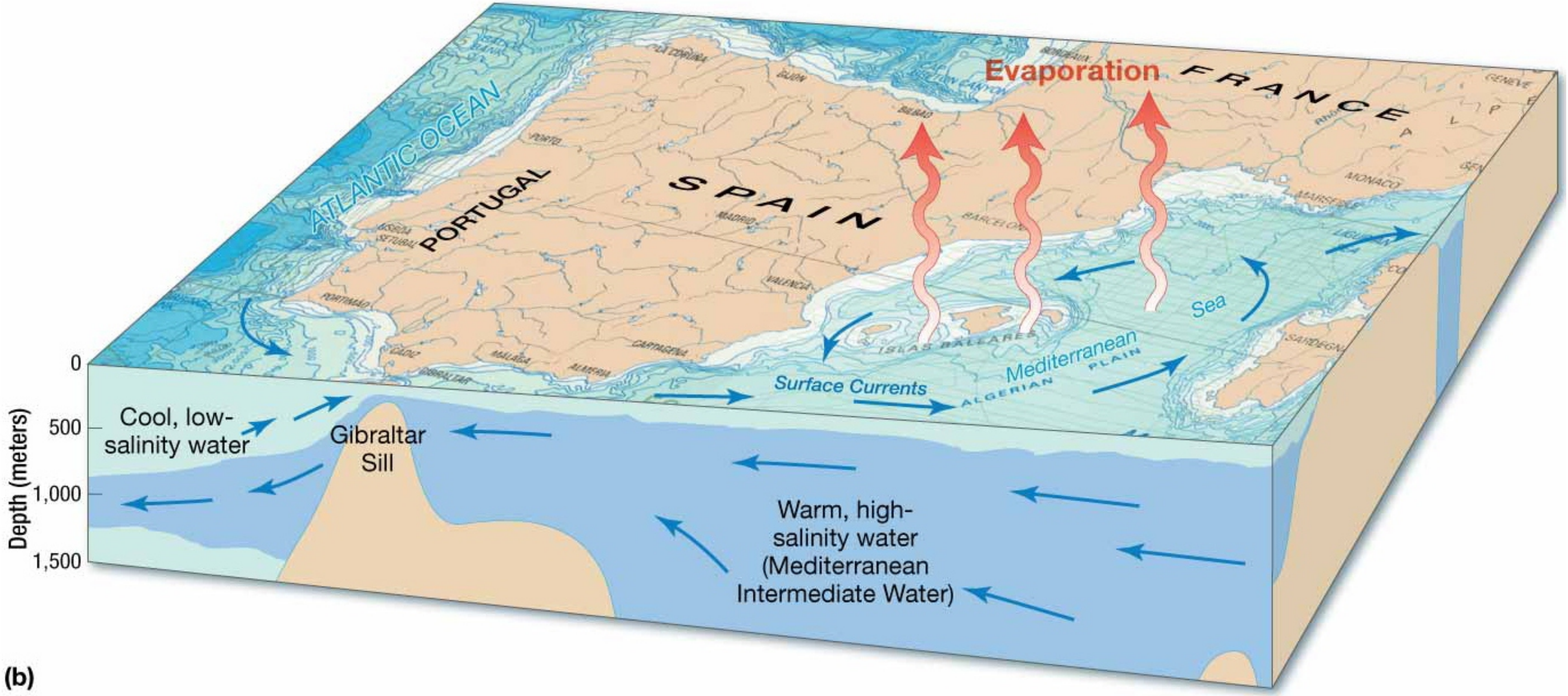
Mediterranean Sea

- Very irregular coastline
- Sill – underwater ridge from Sicily to Tunisia divides Mediterranean into two major basins
- Strong currents through Strait of Messina

Mediterranean Sea Circulation

- Atlantic Ocean surface flow
- High rates of evaporation
- Mediterranean Intermediate Water
  very salty
- Returns to Atlantic Ocean as subsurface flow
- Circulation *opposite* to estuarine circulation

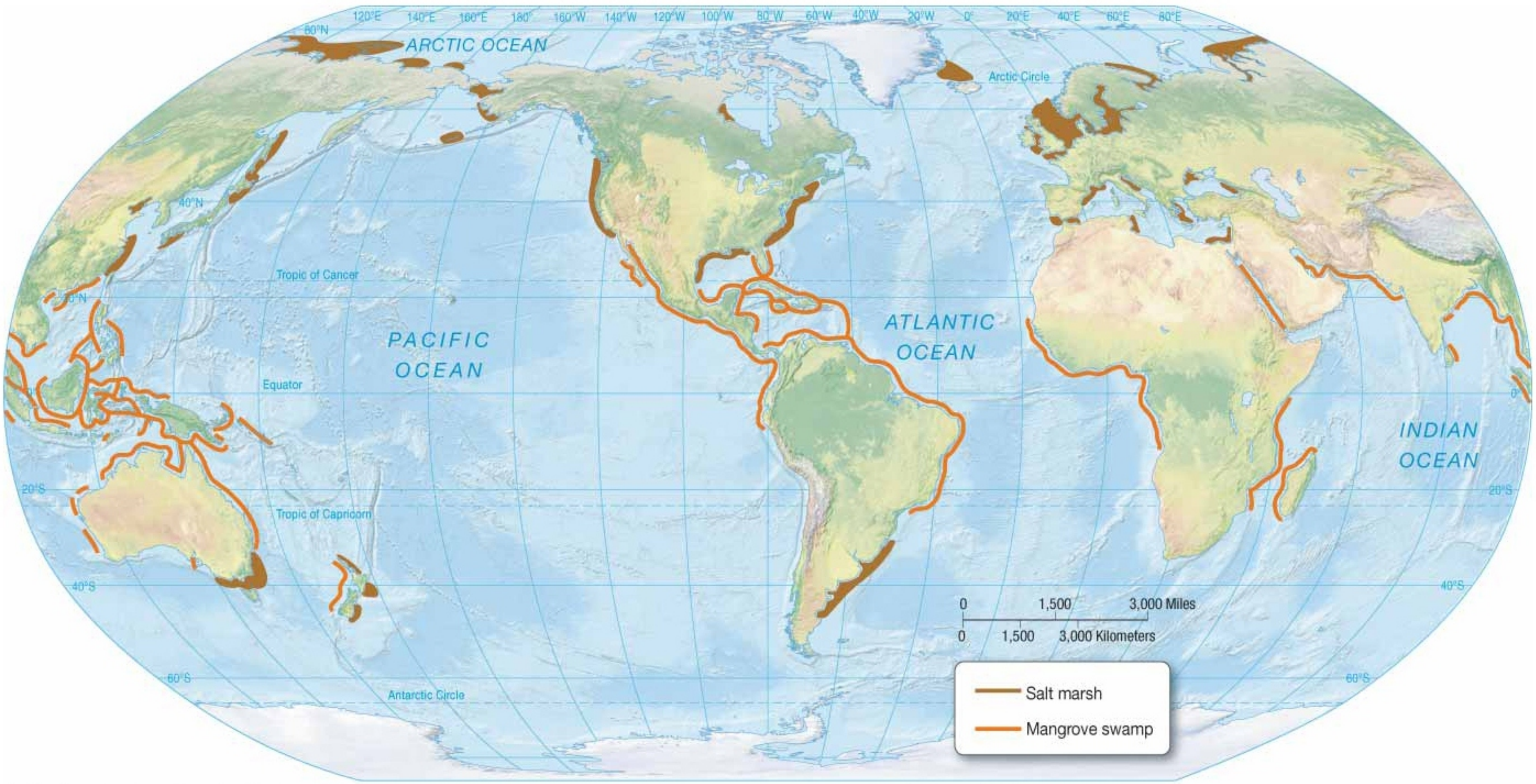
Mediterranean Sea Circulation



Types of Coastal Wetlands

- Ecosystems with water table close to surface
  - Saturated most of the time
- Peat deposits – organic matter accumulations
- Halophytic plants – salt-adapted
- Found along coasts of U.S., Europe, Japan, and eastern South America

Locations of Coastal Wetlands



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Types of Coastal Wetlands

- Salt Marshes
  - Between 30 and 65 degrees latitude
  - Grasses and low-lying plants
- Mangrove Swamps
  - Tropics
  - Trees and shrubs

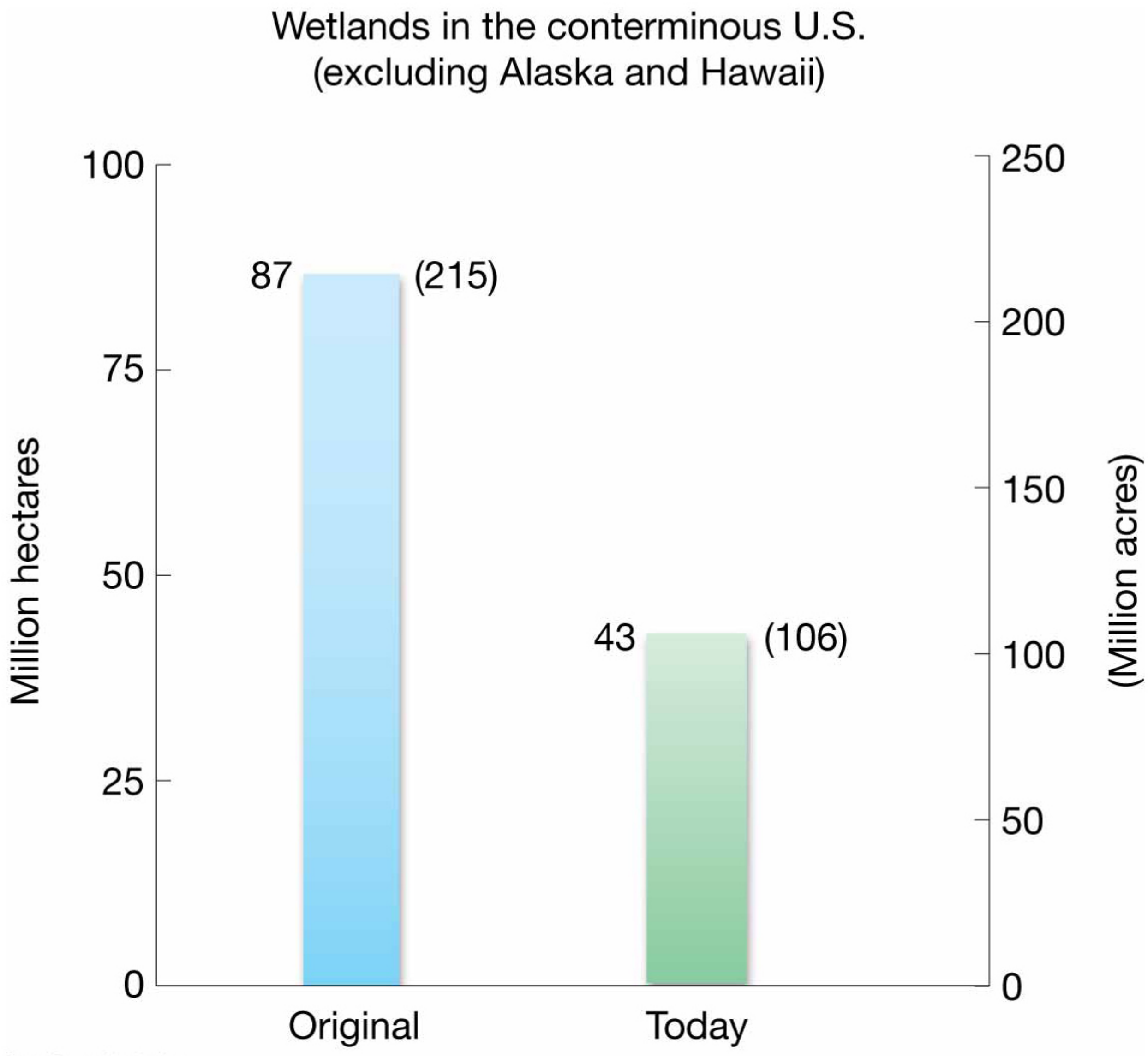
Characteristics of Coastal Wetlands

- Biologically important
  - Nurseries, feeding grounds for commercially important marine animals
- Efficiently cleanse polluted water
- Absorb water from coastal flooding
- Protect shores from wave erosion

Loss of Coastal Wetlands

- Half of U.S. coastal wetlands lost to development (housing, industry, agriculture)
- U.S. Office of Wetland Protection, 1986
  - Minimize loss of wetlands
  - Protect or restore wetlands
- Predicted rise in sea level over next 100 years will destroy or shift wetlands inland

Loss of Coastal Wetlands



Marine Pollution

- Pollution – Any harmful substance or energy put into the oceans by humans
- Harmful to living organisms
  - Standard laboratory bioassay – concentration of pollutant that causes 50% mortality among test organisms
- Hindrance to marine activities
- Reduction in quality of seawater

Marine Pollution

- Environmental bioassay
  - Widely used technique for determining how particular pollutant affects marine organisms
  - Pollutant concentration limits established
- Drawbacks of environmental bioassay
  - Does not predict long-term effect of pollution
  - Does not affect for pollutants combining with other substances
  - Time-consuming and organism-specific

Waste Disposal in Ocean

- Diluting pollutants with huge volume of ocean water
- Long-term effects not known
- Debate about dumping wastes in ocean
  - Some say none at all
  - Some say okay, as long as properly disposed and monitored

Main Types of Marine Pollution

- Petroleum
- Sewage sludge
- DDT and PCBs
- Mercury
- Non-point-source pollution and trash

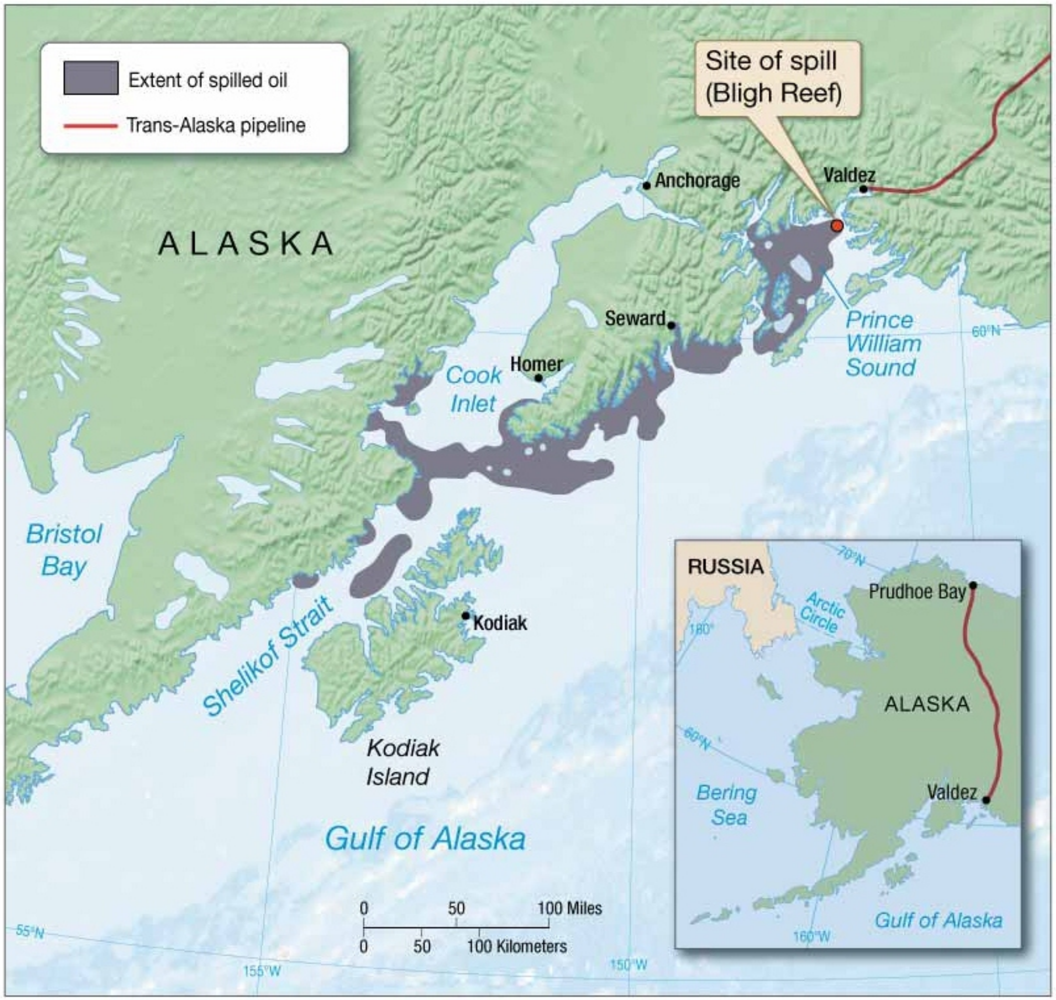
Petroleum

- Oil spills – often from transport accidents
- Some from extraction
  - 2010 Gulf of Mexico *Deepwater Horizon* blowout
- Some from loading/unloading accidents

Exxon Valdez Oil Spill

- March 29, 1989
- Almost 44 million liters (11.6 million gallons) of oil spilled into Prince William Sound, AK
- Many animals, including birds and otters, killed outright
- Long-term consequences unknown

Exxon Valdez Oil Spill



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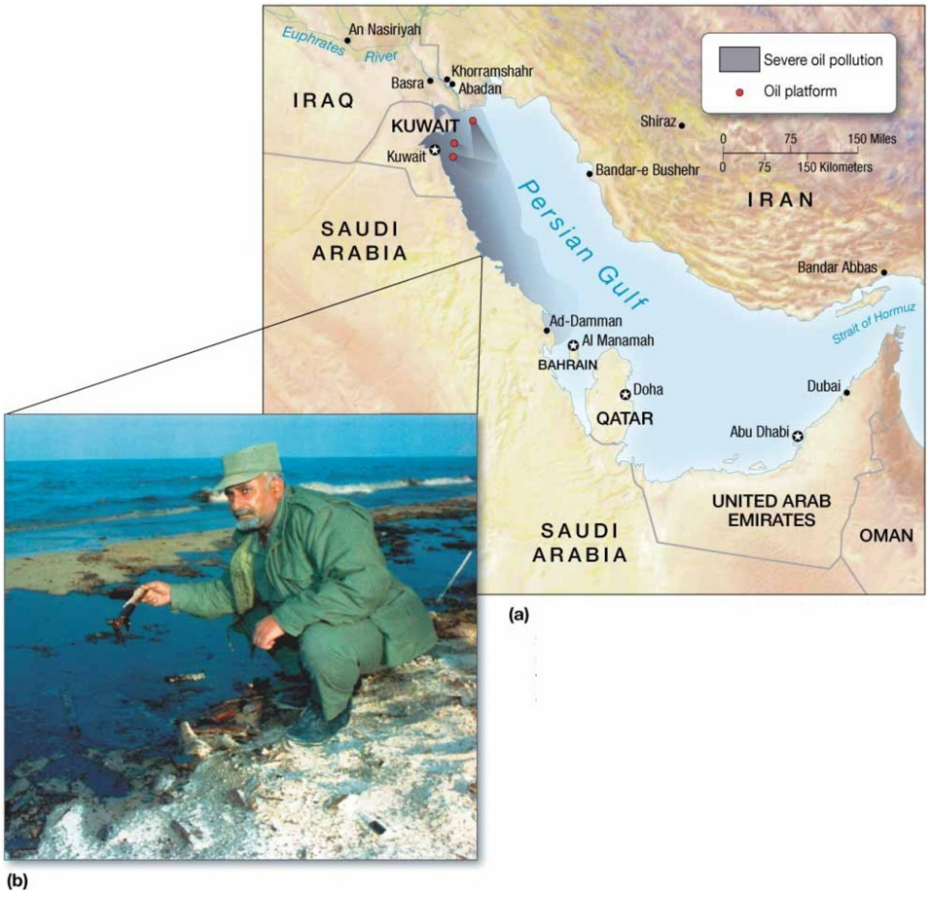
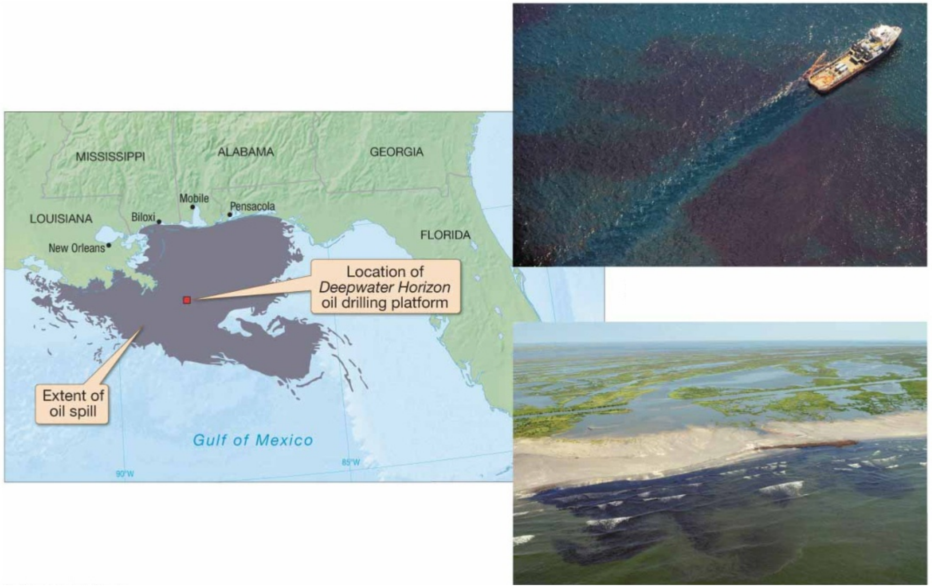
Notable Oil Spills

- Kuwait – intentional dumping of oil into Persian Gulf in 1991
  - More than 908 million liters (240 million gallons) spilled



Notable Oil Spills

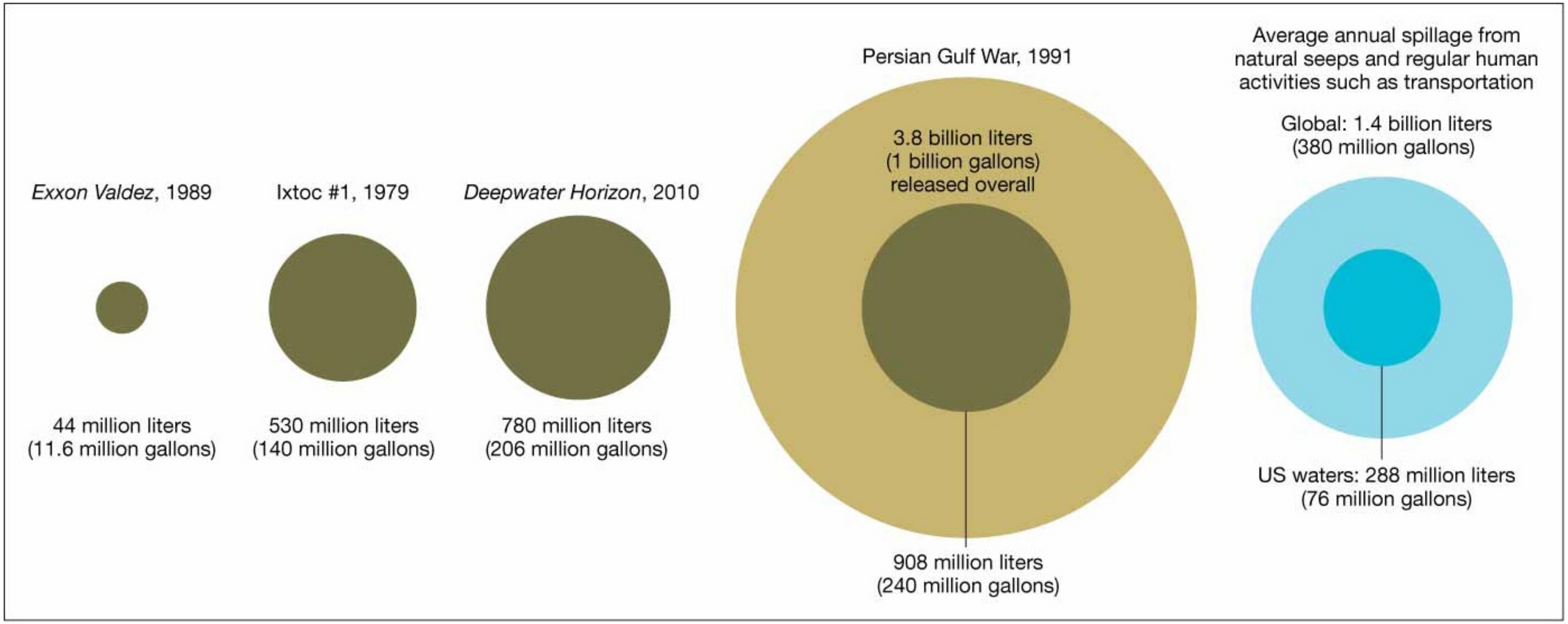
- Gulf of Mexico – 2010 explosion of *Deepwater Horizon* oil drilling platform
  - World's largest accidental ocean oil spill
  - Spilled more than 780 million liters (206 million gallons)



Notable Oil Spills

- Ixtoc #1 Mexico spill
  - World's largest spill from well until 2010
  - Took 10 months to cap
  - Spilled 530 million liters (140 million gallons)

World’s Largest Oil Spills



Petroleum

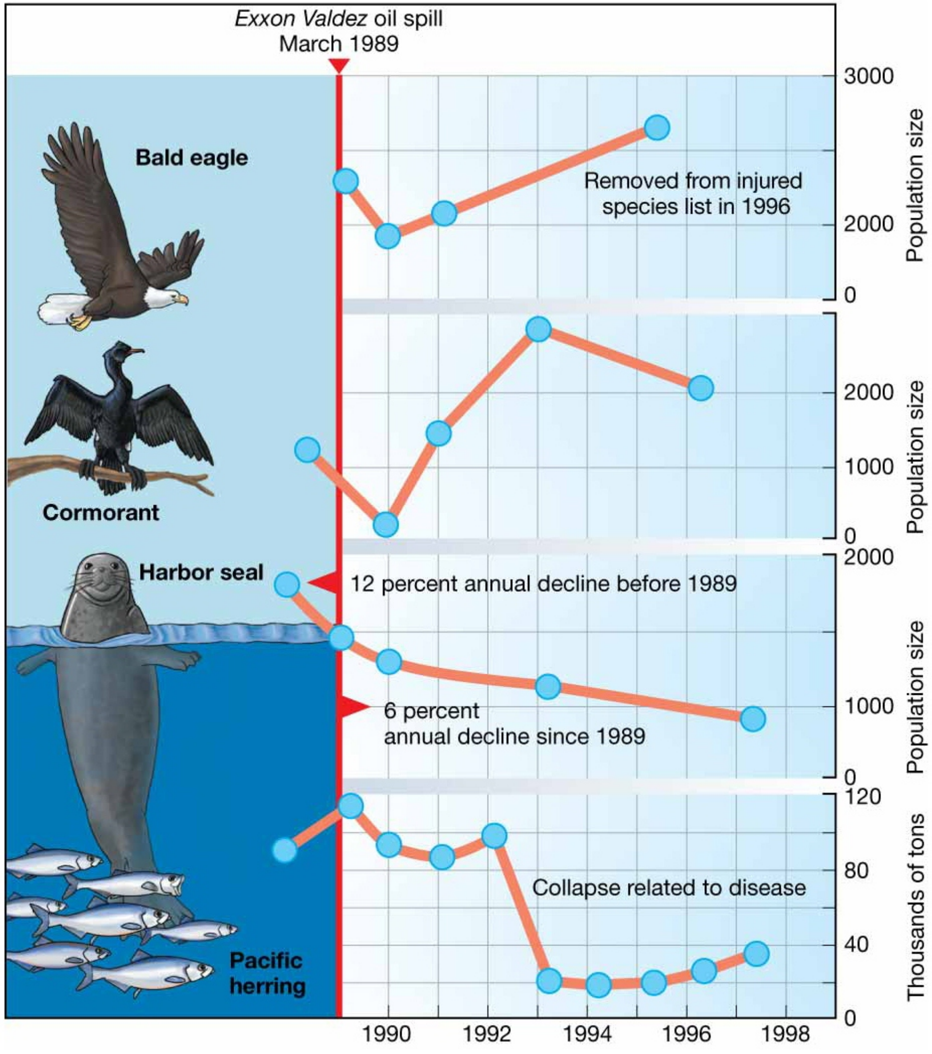
- Made of various hydrocarbons
  - Contains hydrogen and carbon
  - Organic and can be biodegraded
- Toxic compounds in petroleum
- Oil that enters ocean is result of small, frequent, widespread release of oil related to human consumption

Cleaning Oil Spills

- Breaks down by natural processes – tar balls sink
- Skim or absorb oil
- Bioremediation – using bacteria and fungi to biodegrade oil
- Many species bounce back quickly after spills

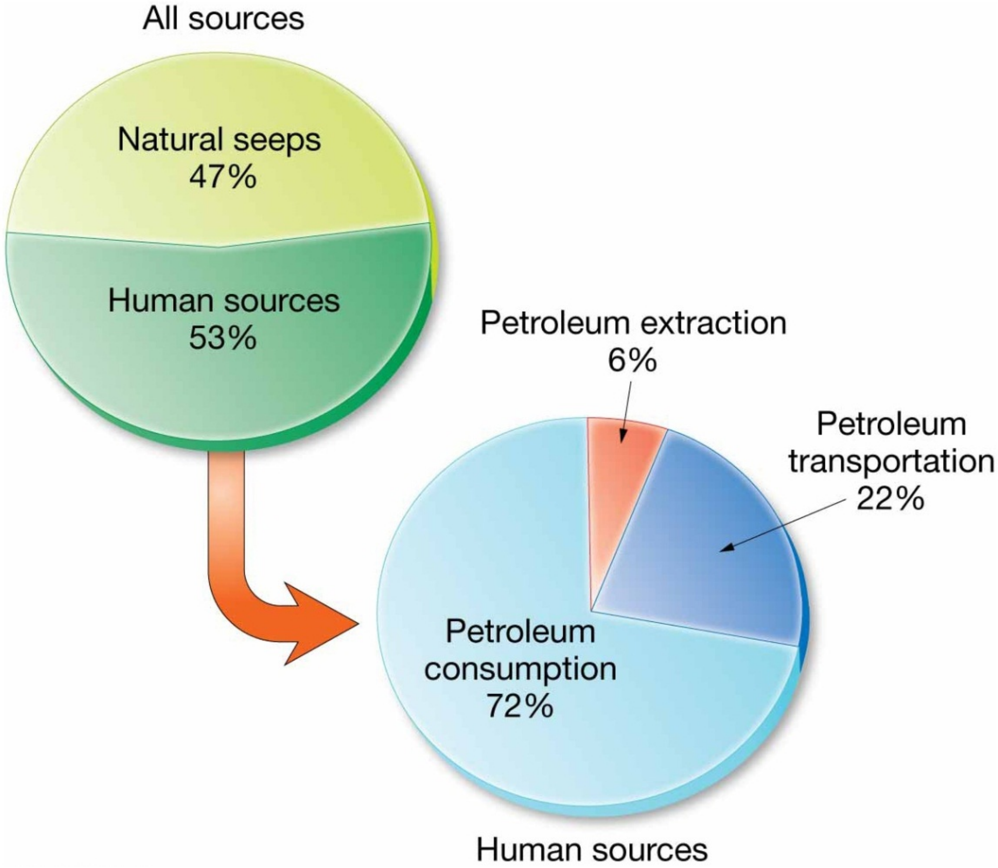
Cleaning Oil Spills

- Marine organism fur or feathers lose insulation properties when covered in oil
- High fatality rates



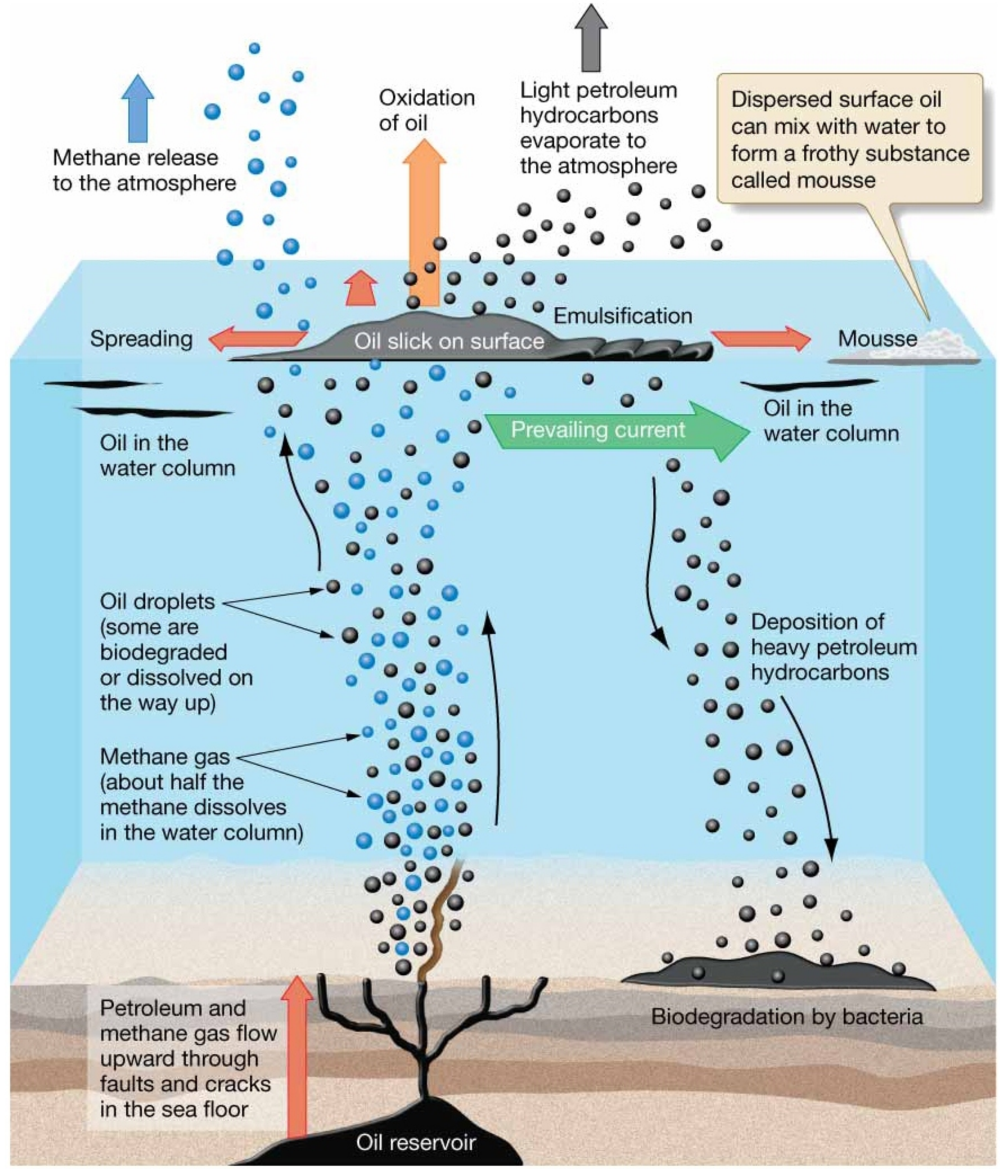
Oil in the Ocean

- Long-term effects
- Oil spills not primary source of ocean oil



Cleaning Oil Spills

- Oil initially floats
- Can disperse
- Can be skimmed
- Oil and water mix to form mousse



Cleaning Oil Spills

- Bioremediation – use of bacteria and fungi to help clean oil spills
  - Releasing bacteria directly into marine environment
  - Creating conditions to stimulate growth of naturally occuring oil-degrading bacteria

Preventing Oil Spills

- Oil Pollution Act of 1990
- Single-hulled tankers barred from U.S. ports, not allowed within 320 km (200 miles) of France and Spain
- Double-hulled tankers
- Redesigning ships

Preventing Oil Spills

- Japanese-owned freighter New Carissa ran aground near Oregon
- Intentionally burned to prevent larger oil spill

Sewage Sludge

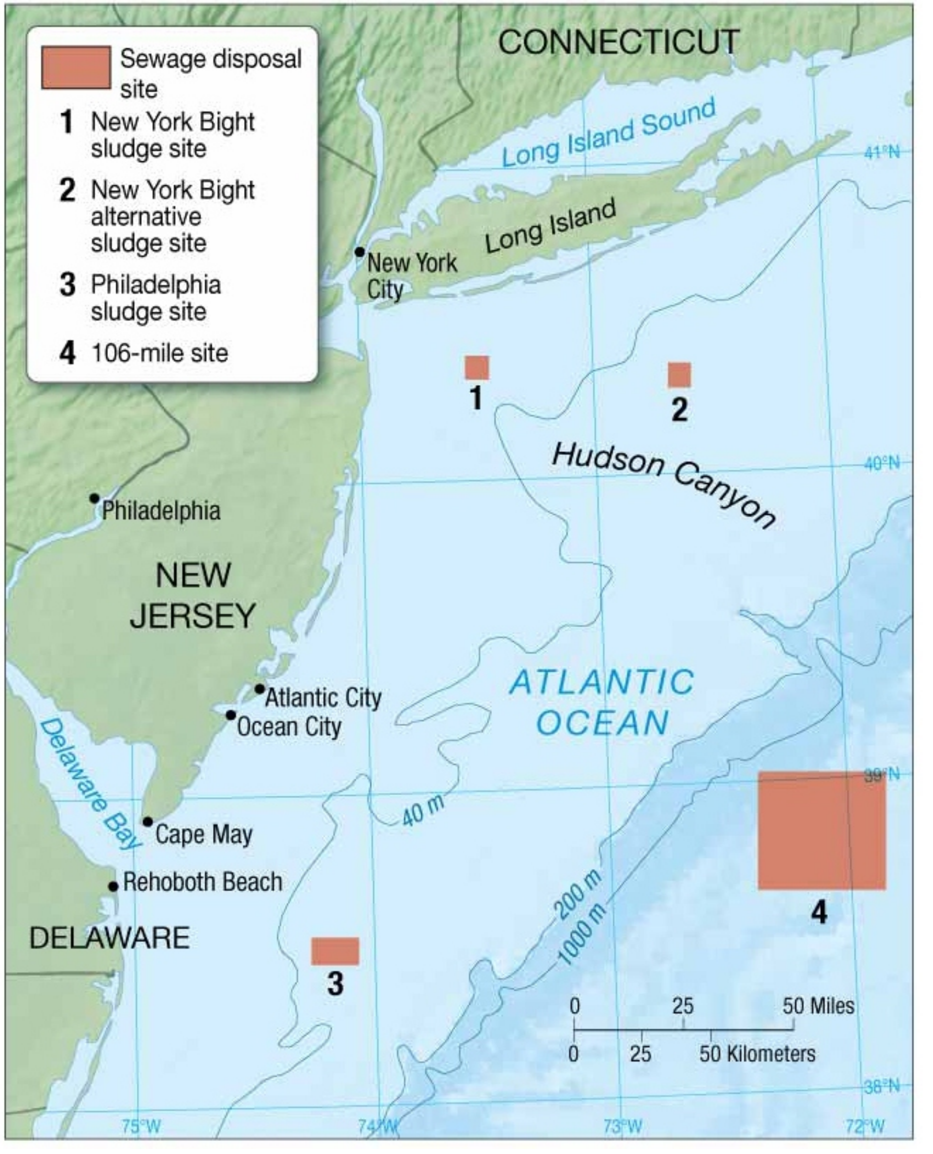
- Semisolid material after treatment
  - Contains human waste, oil, zinc, copper, lead, silver, mercury, pesticides, and other chemicals
- Primary treatment
  - Solids are allowed to settle and dewater
- Secondary treatment
  - Sludge exposed to bacteria-killing chlorine

Sewage Sludge

- No dumping of sludge in ocean after 1981
  - Clean Water Act, 1972
- Many exceptions/waivers

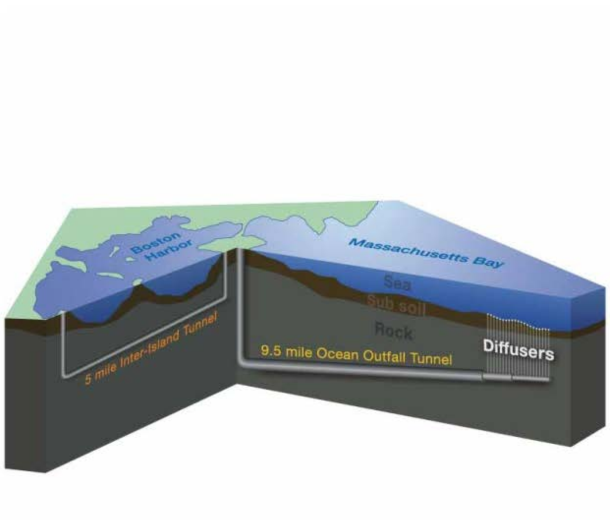
New York's Sewage Sludge Disposal

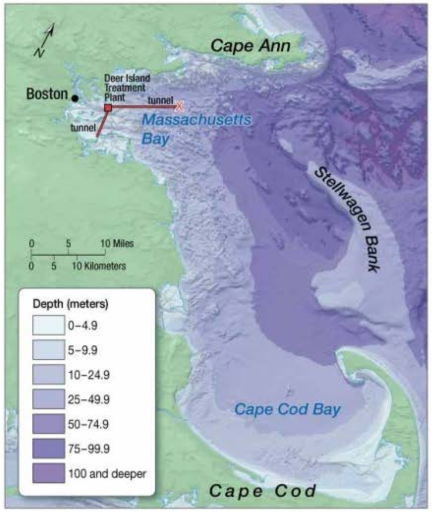
- First, shallow-water sites
- Then (1986), deeper-water site
- Adverse effects on fish
- 1993 – all sewage disposed on land



Boston Harbor Sewage Project

- Court-ordered cleanup of harbor where sewage dumped in shallow water
- Treated sewage released into deep water via tunnels (1998)





DDT and PCBs

- Pesticide DDT (dichloro-diphenyl-trichloroethane)
- Industrial chemicals PCBs (polychlorinated biphenyls)
- Widespread in oceans
- Persistent organic pollutants
  - Toxic
  - Long life, dissolved in seawater
  - Accumulated in food chain

DDT

- Decline in bird populations
- Thin eggshells
  - Long Island osprey
  - California brown pelican
- DDT widely used in 1950s, banned in United States in 1972
- Rebound of some marine bird populations

PCBs

- Once widely used – liquid coolant and insulation in power transformers
- Also in wiring, paints, caulking, hydraulic oils, etc.
- Cause harmful genetic mutations and reproductive issues

DDT and PCBs in Environment

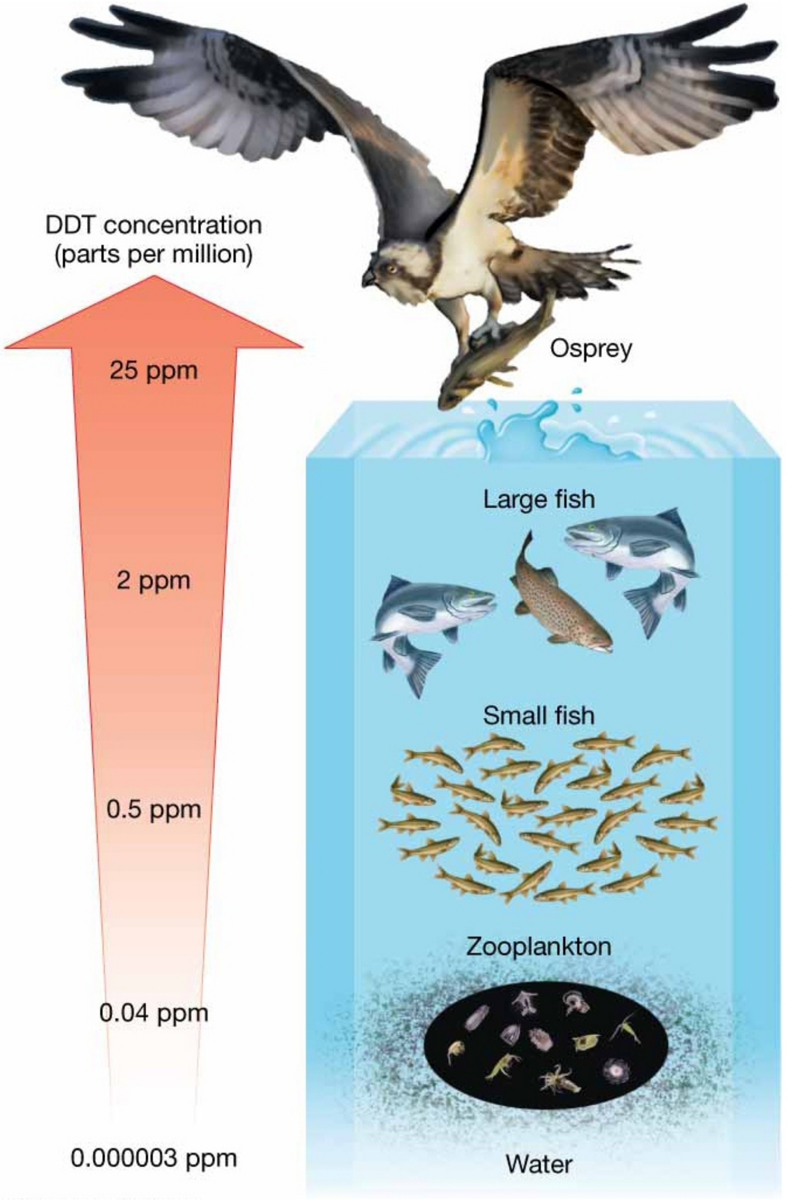
- Banned by most but not all countries
- Sink to sea floor bottom
- Pervasive in marine environment
- Found even in Antarctic

Mercury and Minamata Disease

- Methyl mercury toxic to most living organisms
- Chemical plant in Minamata Bay, Japan, released mercury in 1938
- First reported ecological changes in 1950
- By 1953 humans poisoned
  - Neurological disorder

Bioaccumulation and Biomagnification

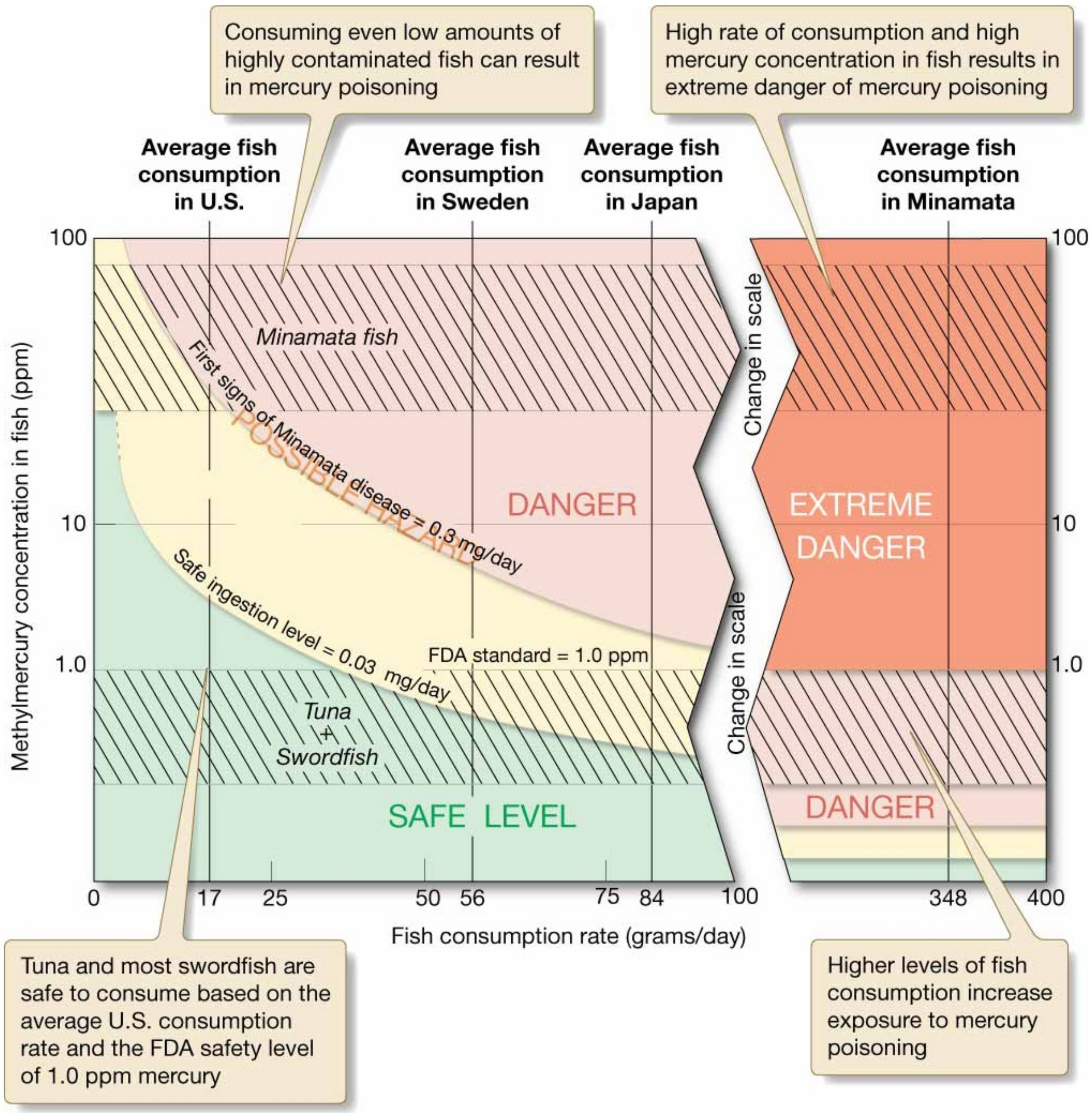
- Bioaccumulation – organisms concentrate pollutant from seawater
- Biomagnification – organisms gain more pollutant by eating other contaminated organisms



Mercury Accumulations

- Safe levels of mercury determined by
  - Rate of fish consumption by people
  - Mercury concentration in fish consumed
  - Minimum ingestion rate of mercury to cause damages

Mercury Accumulations

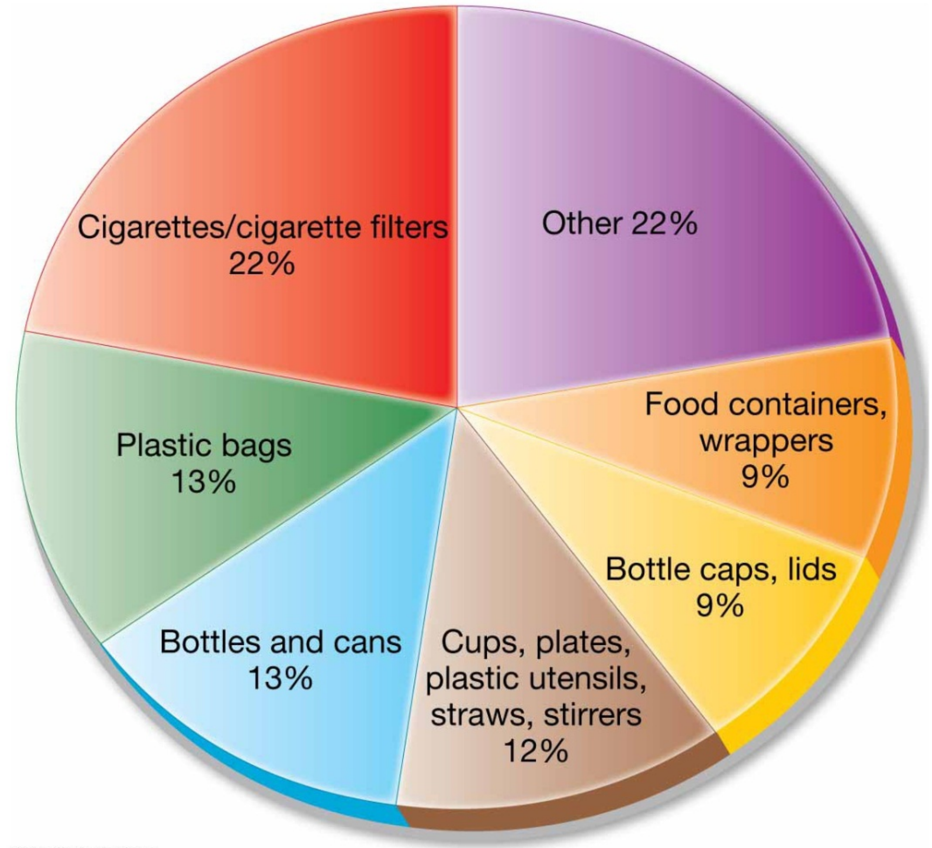


Non-Point-Source Pollution and Trash

- Non-point-source-pollution – poison runoff
- Pollution enters ocean from multiple sources
- Trash
- Pesticides and fertilizers
- Road oil

Non-Point-Source Pollution and Trash

- Difficult to pinpoint origin
- Trash washed down storm drains to ocean
- Road oil, pesticides, fertilizers washed into drains



Ocean Dumping Law

Plastics

- Vast majority of marine debris
- 80% of marine debris from land sources
  - Most of it plastic
- Not readily biodegradable

Plastics

- Entangle fish, marine mammals, and birds
- Plastic bags choke turtles
  - Mistake for jellyfish
- Some plastics attract poisons, e.g., DDT, PCBs

Effects of Plastic Marine Trash

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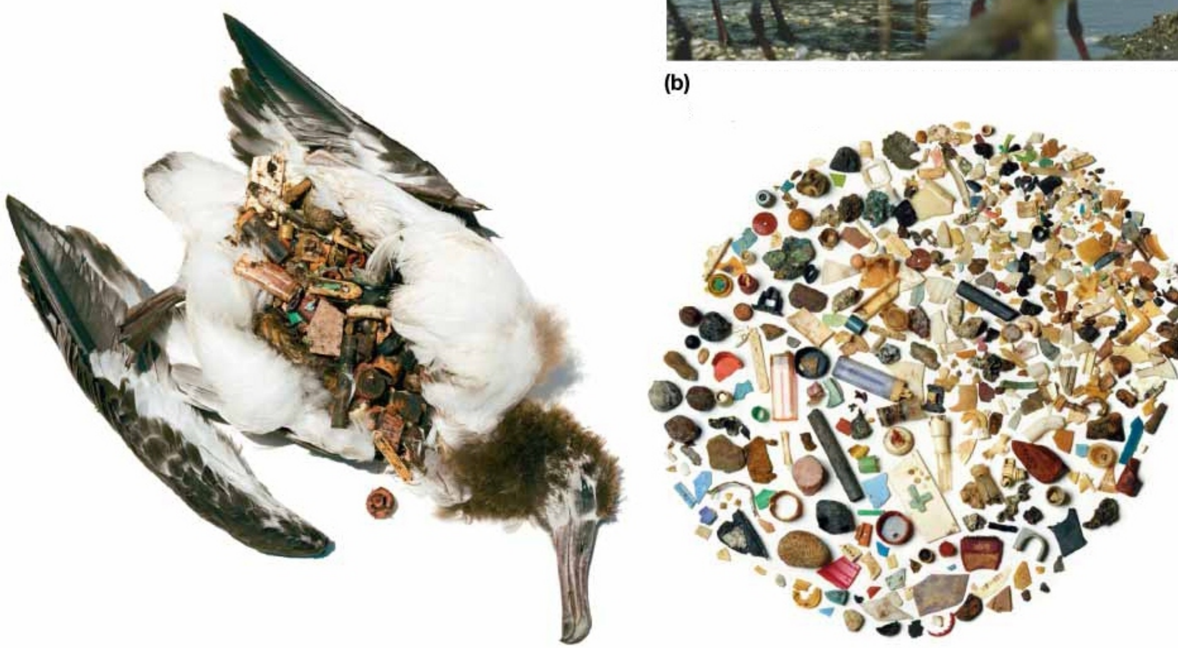

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Plastics

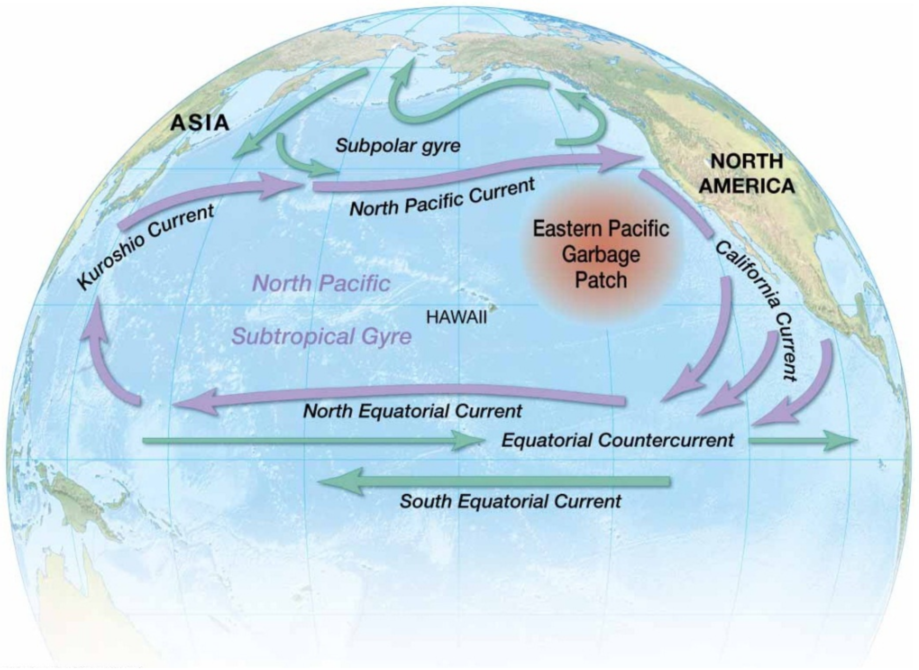
- Debut in 1862
- Commercial development during World War II
- Disposal strains environment
  - Lightweight – float
  - Strong – entangle
  - Durable – don't biodegrade
  - Inexpensive – mass produced

Plastics

- Nurdles – small pre-production plastic pellets
- Found in ocean and all beaches due to spillage
  - Orange County, CA – 98% of beach debris are nurdles

Plastics in the Ocean

- Floating plastics photodegrade
  - Break into smaller pieces
- Marine plastic particles increasing significantly
- Regions of floating trash
  - Eastern Pacific Garbage Patch



Laws Regarding Ocean Dumping

- In 1988 International Convention for the Prevention of Pollution from Ships (MARPOL):
  - Proposed treaty banning disposal of plastics
  - Regulating other trash dumping at sea
  - 122 nations ratified by 2005
- Facilities not available for garbage disposal

Biological Pollution: Non-Native Species

- Originate elsewhere, introduced by humans intentionally or accidentally
- Outcompete and dominate native populations
- Invasive species cause extensive damage annually

Biological Pollution – Non-Native Species

- *Caulerpa taxifolia* – tropical sea weed
  - Cold-tolerant clone introduced to Mediterranean, overwhelmed ecosystem
  - Also in Southern California, Australia

Biological Pollution – Non-Native Species

- Zebra mussel
  - Invaded Great Lakes of North America
  - Drove out local mussels
  - Altered ecology of freshwater lakes, streams
  - Blocked water pipes of industrial facilities

End of CHAPTER 11
The Coastal Ocean