



# Ch. 12: Freshwater, Oceans, & Coasts

**~71% of Earth is  
covered in water**

# Aquatic Biomes

- Determined by salinity, depth, & water flow



**Freshwater**

- Lakes
- Ponds
- Streams
- Rivers
- Wetlands

**Saltwater**

- Intertidal Zone
- Kelp Forest
- Coral Reef
- Open Ocean
- Deep Sea

## Estuaries

- Salt Marshes
- Mangroves

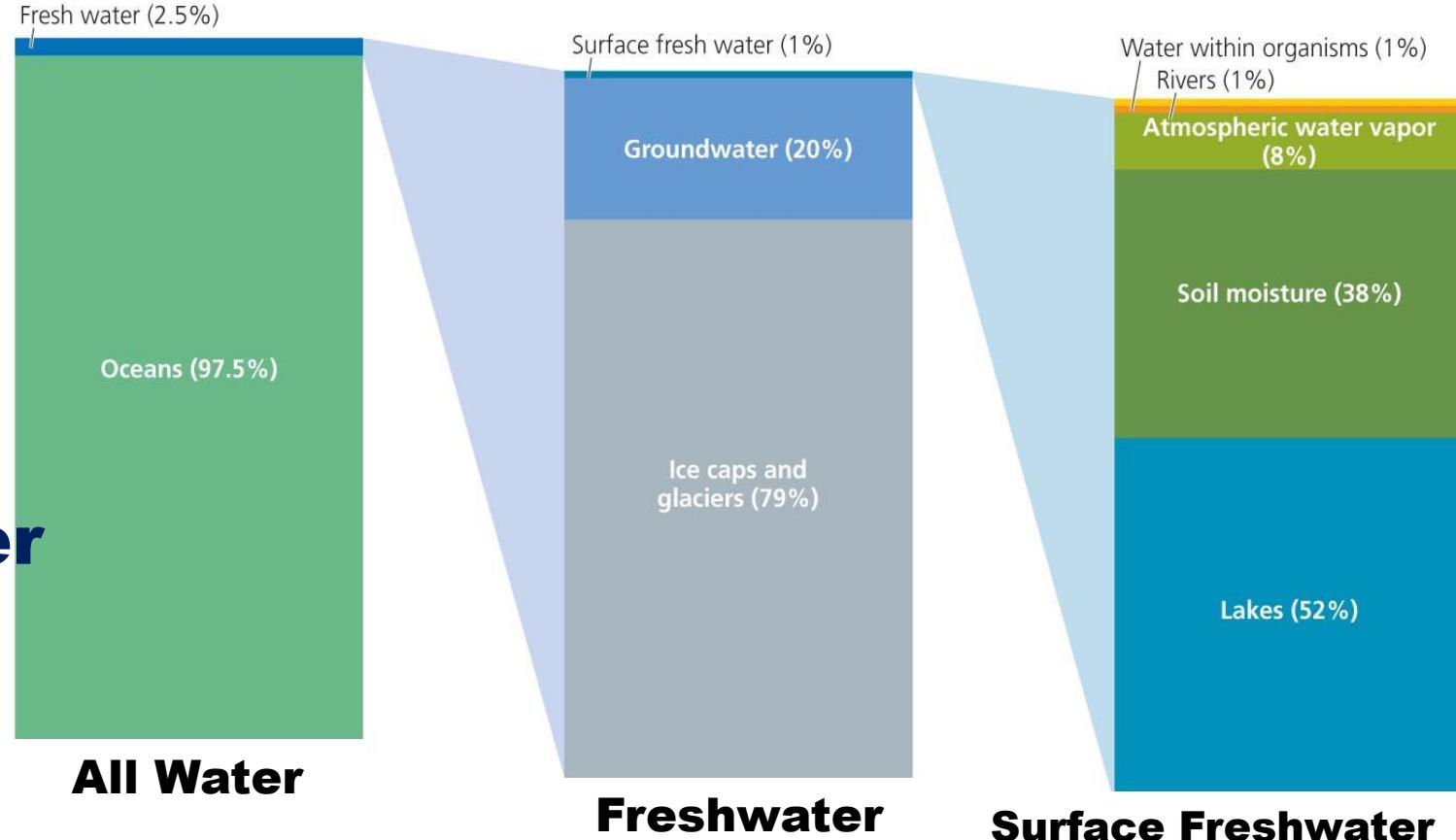


- **Estuaries:** Boundary between fresh & salt water ecosystems - both fresh & saltwater flows into estuaries
- Also form a border between terrestrial & marine systems
- **Mangroves (trees), Marshes (grasses, non-woody plants)**

# Freshwater systems

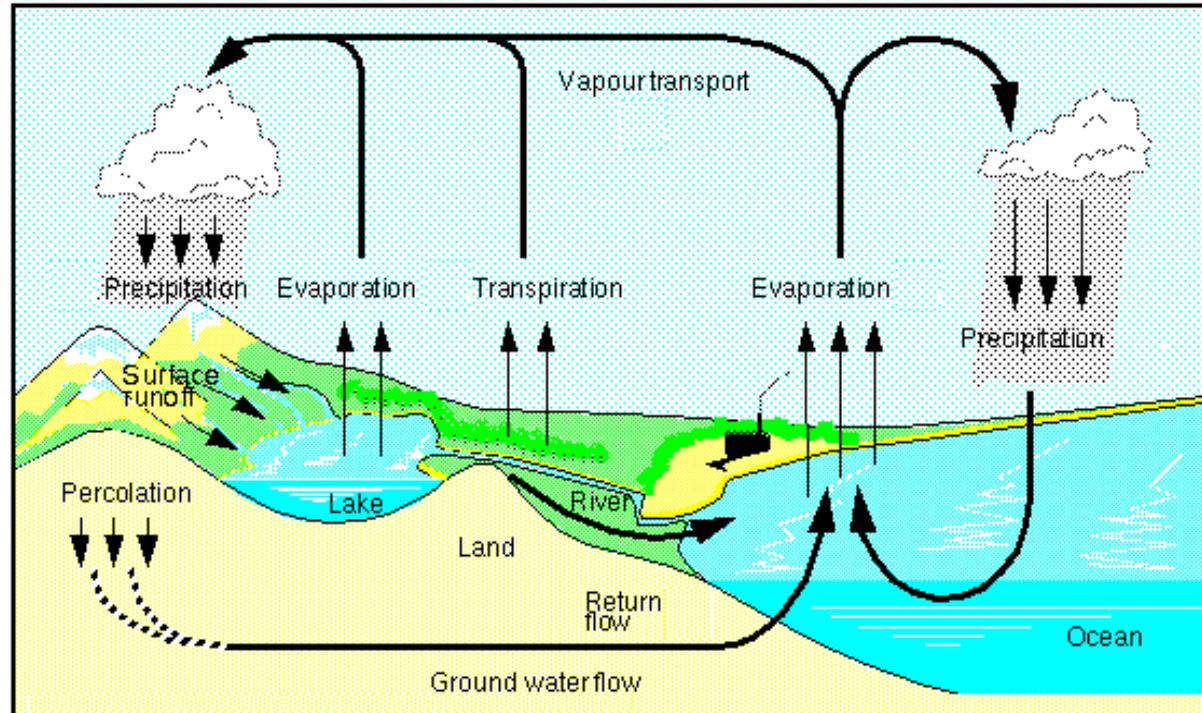
- Water may seem abundant, but drinkable water is rare
- Freshwater: relatively pure, with few dissolved salts = 2.5% of Earth's water
  - Most is tied up in glaciers, ice caps, & underground aquifers

**Surface water = 1% of freshwater**



# Water is renewed & recycled

- As water is cycled it redistributes heat, erodes mountains, builds river deltas, maintains ecosystems & organisms
- Rivers: flow of fresh water across the land into the sea, a lake, or another river
  - **Tributary:** small rivers flowing into larger one
- Watershed: area of land drained by a river system
- Riparian: river-side areas that are productive & species-rich



# River floodplains

- Easy access to freshwater & fertile soils made rivers good areas for agriculture & communities



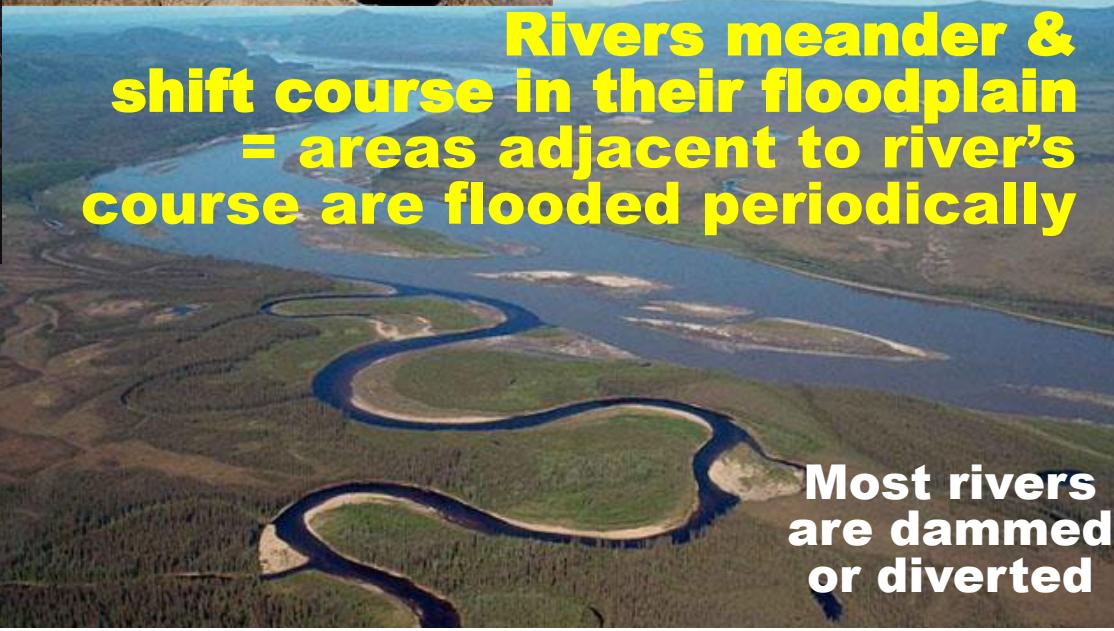
Periodic floods resulted in channelization to contain river



Santa Ana River today



Rivers meander & shift course in their floodplain = areas adjacent to river's course are flooded periodically

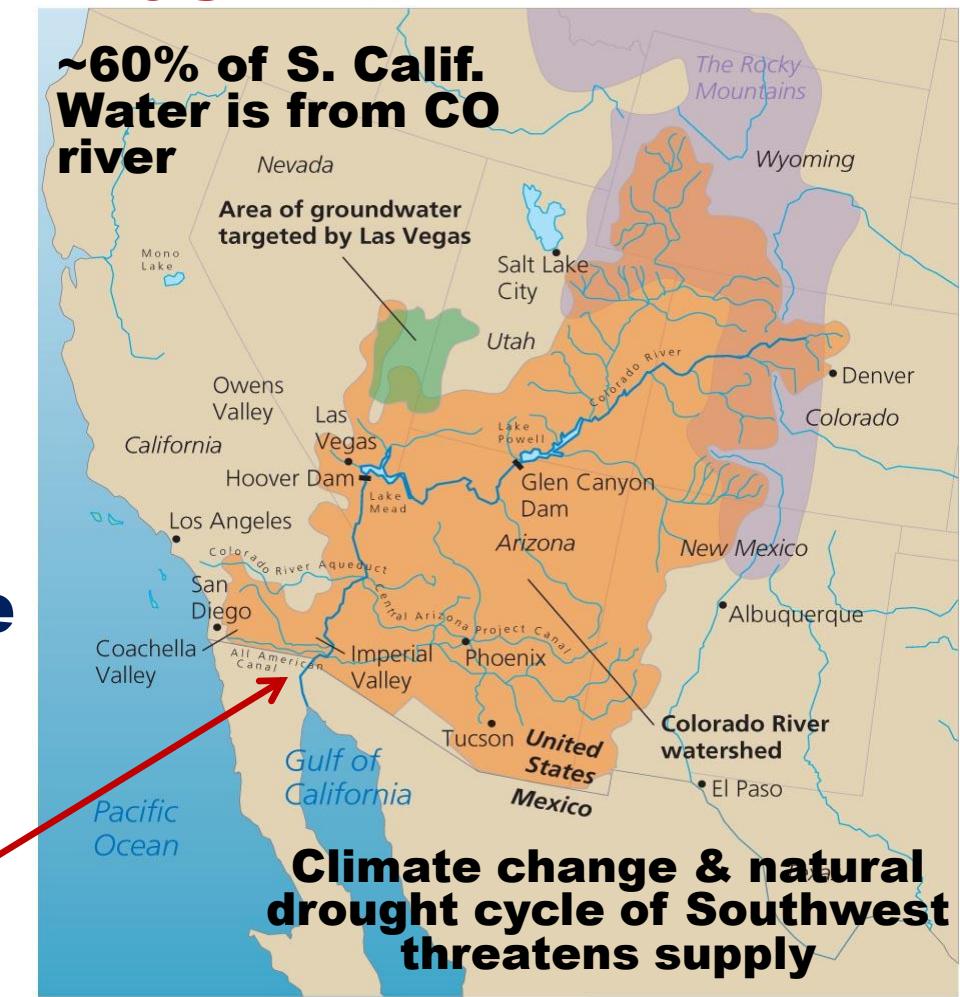


Most rivers are dammed or diverted



# The Colorado River

- **Originates in Rocky Mountains & drains into the Gulf of Calif.**
- **It cut the Grand Canyon, but dams & water extraction has reduced it to a trickle**
- **Dams provide flood control, recreation, & hydroelectric power**
- **7 states (30 million people) share the river**
- **Droughts & overuse are threatening supplies**
- **Only a trickle now makes its way to the once lush Gulf delta**



# Lakes & ponds

- **Bodies of open, standing freshwater (FW), seas are slightly saline (lost ocean connection)**
- **Many created by tectonic activities or glaciation**
- **Found in mountainous regions, areas with high rainfall or history of glaciation, or near rivers that feed & drain them**
- **World's largest lakes: Caspian Sea (Eurasia), Great Lakes (North America) Victoria (Africa)**



# Freshwater Wetlands

- Soil is saturated with shallow standing water
- Mashes: shallow water allows plants grow above the surface
- Swamps: shallow water in forested areas



Swamps can  
be made by  
beavers  
damming  
streams

# Freshwater Wetlands

- **Bogs:** ponds covered in thick floating mats of vegetation (peat)
  - Common at high latitudes (Ireland, Scotland, N. Canada) can be acidic due to slowly decaying plants
- **Vernal Pools:** Seasonally wet (rainy season) followed by dry period
  - Species are adapted to seasonal drying



# Wetlands are valuable

- Critical habitat for wildlife

- They slow runoff, reduce flooding, recharge aquifers, & filter pollutants

- People have drained wetlands, mostly for agriculture

- Southern Canada & the U.S. have lost over half of their wetlands

- 2023 Supreme Court narrowed definition of “Waters of the US,” which removed Clean Water Act protection for ~84% of US wetlands

- As wetlands disappear, we lose ecosystem services

- Wetland restoration returns habitat & services

U.S. Army Corps of Engineers are tasked with protecting & restoring wetlands



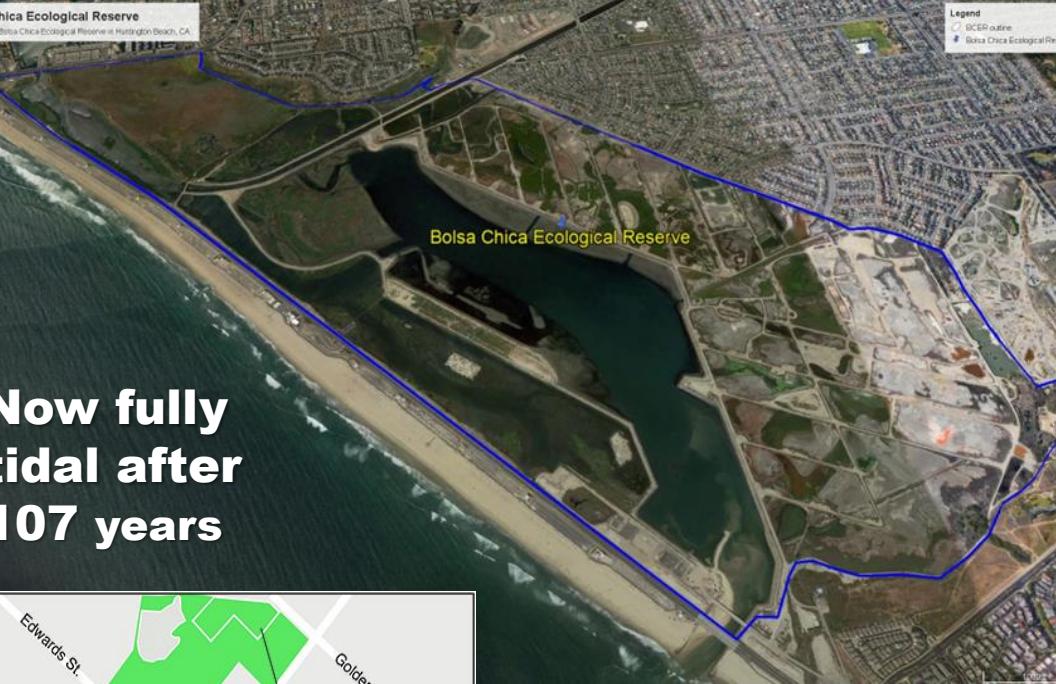
# Restored in 2006

Doubled in size to 1,247 acres

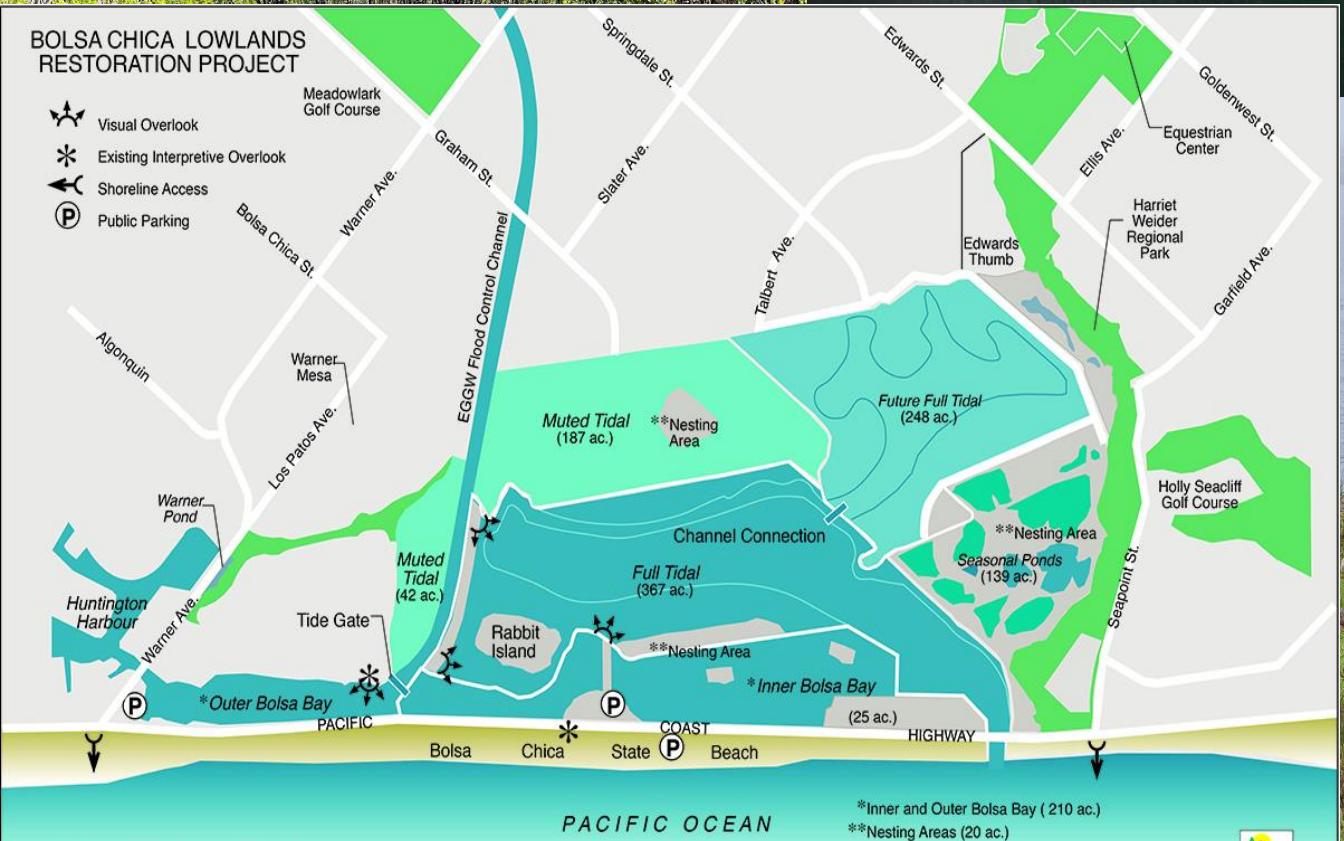
# BOLSA CHICA

HUNTINGTON BEACH | CALIFORNIA

Ecological Reserve



Now fully  
tidal after  
107 years



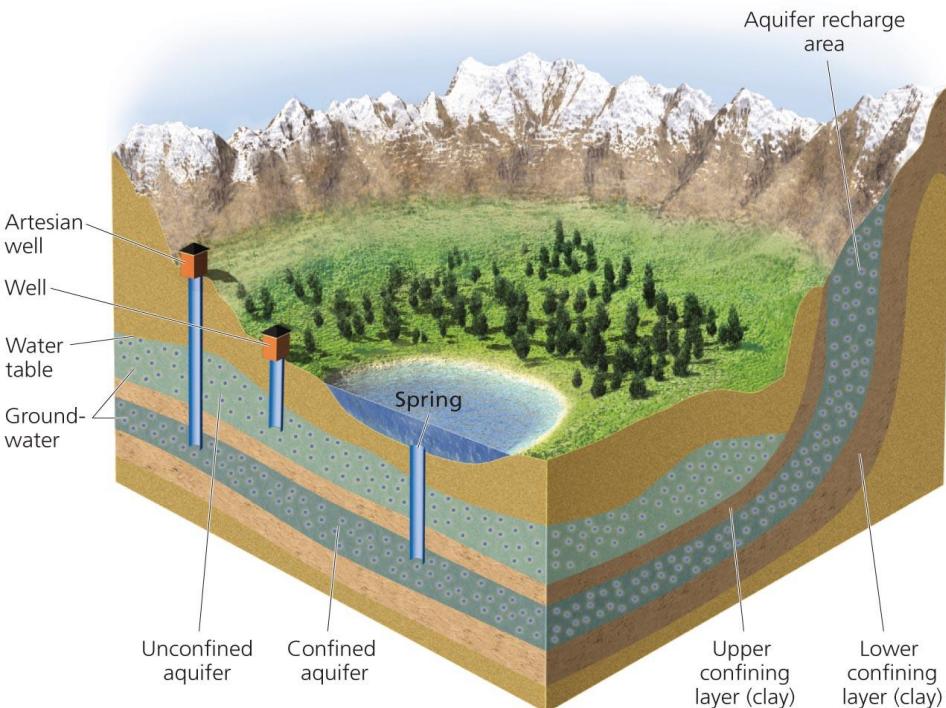
10,000 shorebirds  
visit annually

Nesting sites for  
endangered species



# Groundwater

- Water beneath surface held in pores in soil or rock = 20% of the Earth's freshwater supply
- **Aquifers:** porous, sponge-like formations of rock, sand, or gravel that hold water
- **Recharge zone:** area where water infiltrates Earth's surface & reaches aquifers
- Groundwater's average age is 1,400 years
  - Can be tens of 1000's of years old
- Becomes surface water through springs or human-drilled wells



# Groundwater is easily depleted

- Aquifers recharge slowly
  - Used by 1/3 of all people
- As aquifers are mined, water tables drop
  - Salt water intrudes in coastal areas
- Ground subsides (sinks) & sinkholes occur as ground gives way unexpectedly
  - Then, aquifers can't recharge (refill) & wetlands dry up
- California's new Sustainable Groundwater Management Act limits groundwater pumping

(b) Sinkhole in Florida



(a) 16th-century chapel in Mexico City



# California's Central Valley Aquifer

**Has permanently lost capacity due to over-pumping & long periods of drought**

**CA enacted the Sustainable Groundwater Management Act (2014)**

**Prior to, water management had been unregulated & voluntary**



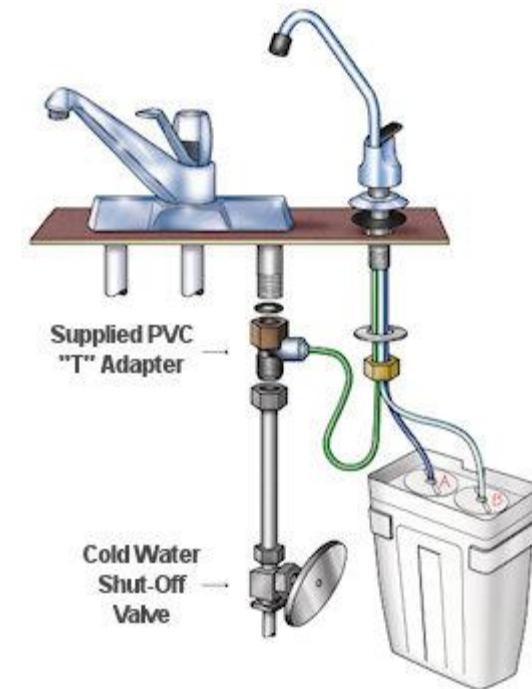
# Bottled water

- Most withdrawn from underground aquifers
  - Average American drinks 29 gallons/year
- People drink bottled water for portability, convenience, think it tastes better or is healthier
- Bottled water is usually no safer than tap water
  - Heavily packaged & travels long distances using fossil fuels
  - Energy costs are 1,000–2,000 times greater than those of tap water
  - Few bottles are recycled (~80% in U.S. end up in landfill)
  - Corporations move in, deplete water, & move away



# Bottled water alternatives

- Filter tap water at home with filter pitchers or under the sink filtration system (carbon filter, or reverse osmosis)
  - Removes chlorine & contaminants

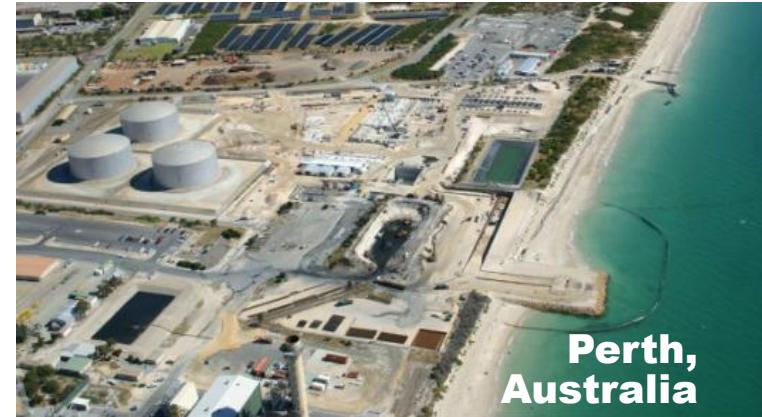


- Then, fill BPA-free bottles when on the go (metal, glass)



# Desalination

- Removal of salt from seawater or farm runoff
  - **Distilling:** evaporates & condenses ocean water
  - **Reverse osmosis:** forces water through membranes to filter out salts
- Expensive, requires fossil fuels, kills aquatic life, & produces salty waste
- Most facilities are in arid Middle East with little freshwater & oil is cheaper than water
- Sustainable when powered with renewable energy, salts collected & recycled, minimize marine species impacts at intake



Perth,  
Australia



# The Carlsbad Desalination Plant Process

START

## 1) The Process Begins

The ocean flows into  
Aqua Hedionda Lagoon

PACIFIC OCEAN

## 2) Pumping Seawater

600 million gallons is pumped into system.

4) Desalination Starts  
By filtering seawater through  
osmotic membrane filters,  
over 99.8% of salt is removed  
and formed into a brine.

Screens keep  
sea life out  
of system.

6) Over 45 Million Gallons of  
Drinking Water Produced  
Producing 7-10% of potable  
water for San Diego County  
businesses, schools and  
homes everyday.

5) The Brine Is Put  
Back Into the Ocean  
By diluting brine to lower  
salinity of 36.2 ppt, we  
minimize harm to sea  
life (normal is 33.5 ppt)

500 Million Gallons

Encina  
Power  
Plant

100 Million Gallons

FINISH

drips

## How Does It Affect San Diego County?

By using PX pressure exchangers, this process will reduce CO<sub>2</sub> emissions by 41,000 metric tons per year. That is equivalent to taking 8,542 cars off the roads.

When the Carlsbad Desalination Plant comes online in 2016, it will be the largest, most technologically advanced and energy efficient desalination process in the western hemisphere.

# Carlsbad Desalination Plant

San Diego County  
Opened Dec. 2015

Produces enough  
water to serve  
500,000 people

Uses Reverse  
Osmosis System



1%

# Doheny Ocean Desalination Project - Dana Point

**2029 proposed opening – produce 5 million gallons/day**



# Reducing demand & eliminating waste

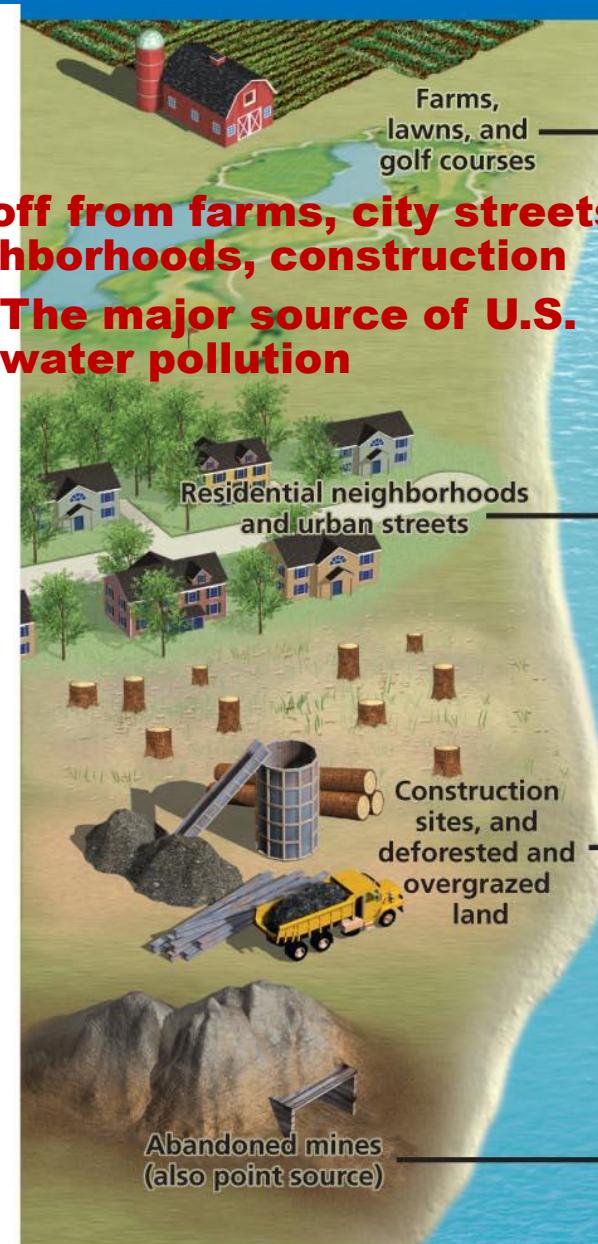
- Use excess surface water runoff to recharge aquifers
- Recycle wastewater, fix leaks
- Install low-flow faucets, showerheads, washing machines, & toilets
- Rainwater harvesting: capturing rain from roofs
- Gray water: collecting & reusing wastewater from showers, sinks, wash machines
- Water gardens at night, use drip irrigation
- Eat less meat (livestock use lots of H<sub>2</sub>O)



Xeriscaping  
uses plants  
adapted to arid conditions

# Freshwater pollution sources

## Non-point pollution: many diffuse sources



Fertilizers, herbicides, and pesticides

Nutrients, waste, and bacteria

Salt on winter roads; oil, grease, and chemicals from urban runoff

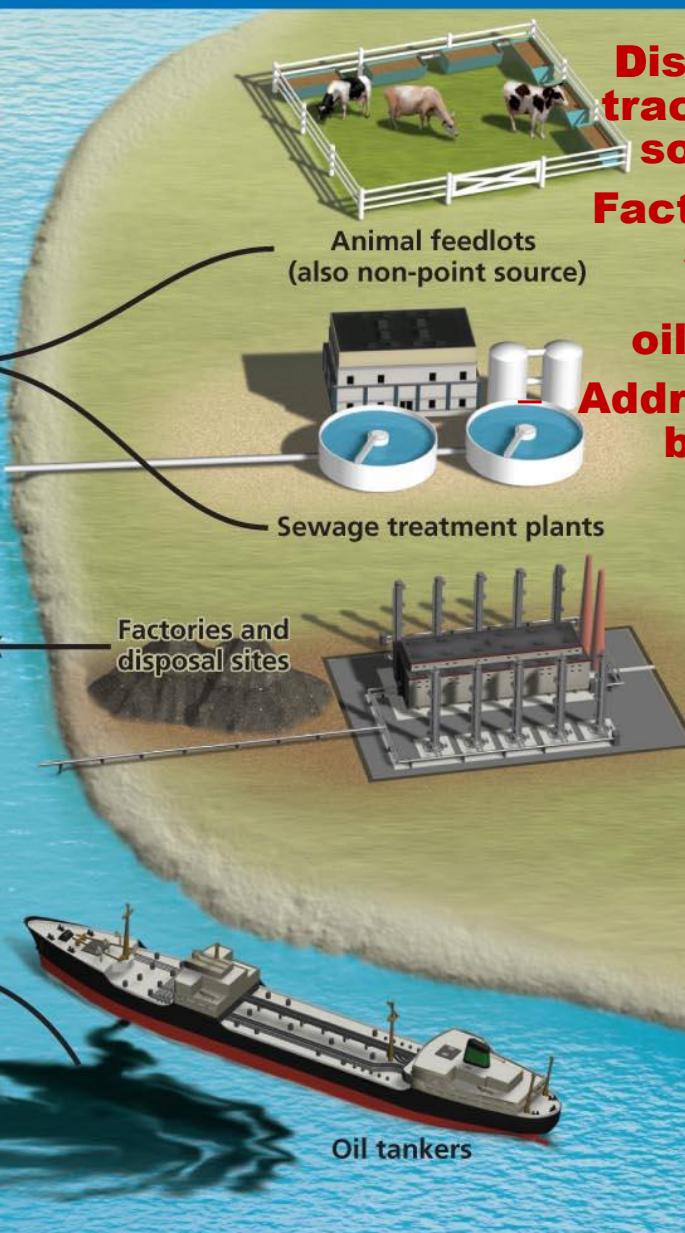
Industrial waste and toxic chemicals

Eroded soil

Oil spills

Acid drainage

## Point-source Pollution:



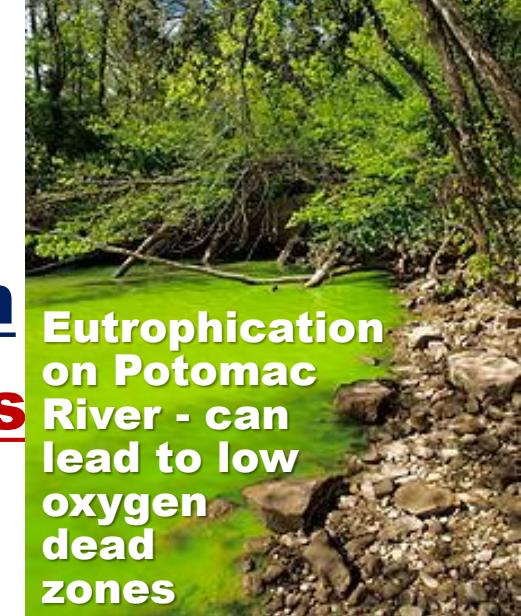
Discrete, traceable sources

Factories, sewer pipes, oil spills

Addressed by U.S. Clean Water Act

# Freshwater pollutants

**1. Nutrients from fertilizers, farms, sewage, lawns, golf courses, & wastewater leads to eutrophication**



**2. Pathogens & waterborne diseases inadequately treated human or animal waste (from feedlots)**

**–Need sewage treatment, disinfection of drinking water, proper sanitation facilities, & education**

**3. Toxic chemicals: Pesticides, petroleum products, synthetic chemicals, arsenic, lead, mercury, PFAs, acids (acid rain, mine drainage)**



**4. Sediment: agriculture, land development, mining, clear cutting trees (soil erosion makes water murky, fills in water bodies)**

# Legislative efforts reduce pollution

- Water pollution was worse decades ago
  - Citizen activism & government response resulted in legislation during 1960s & 1970s
- Clean Water Act (1972): regulated by EPA
  - Illegal to discharge pollution without a permit, sets standards for industrial waste water, funded sewage treatment plants
- CWA under threat: (1) narrowed federal water protections for wetlands, (2) pause in water infrastructure investments, (3) reduction in enforcement of CWA, allowing increased violations
  - 27% of Americans exposed to unsafe drinking water (2025)
- Best to prevent pollution then to clean it up (saves money too!)



# Treating water

- Treated drinking water is widespread & successful in developed nations
- Before water reaches the user, it is chemically treated, filtered, & disinfected
- The EPA sets standards for over 90 drinking water contaminants
- Wastewater from homes, industry, businesses is treated before release into environment
  - Septic systems or municipal sewer systems
    - In populous areas, sewer systems carry wastewater to treatment locations



Orange County Sanitation District  
In Huntington Beach



Working to treat storm water runoff from adjacent Santa Ana River

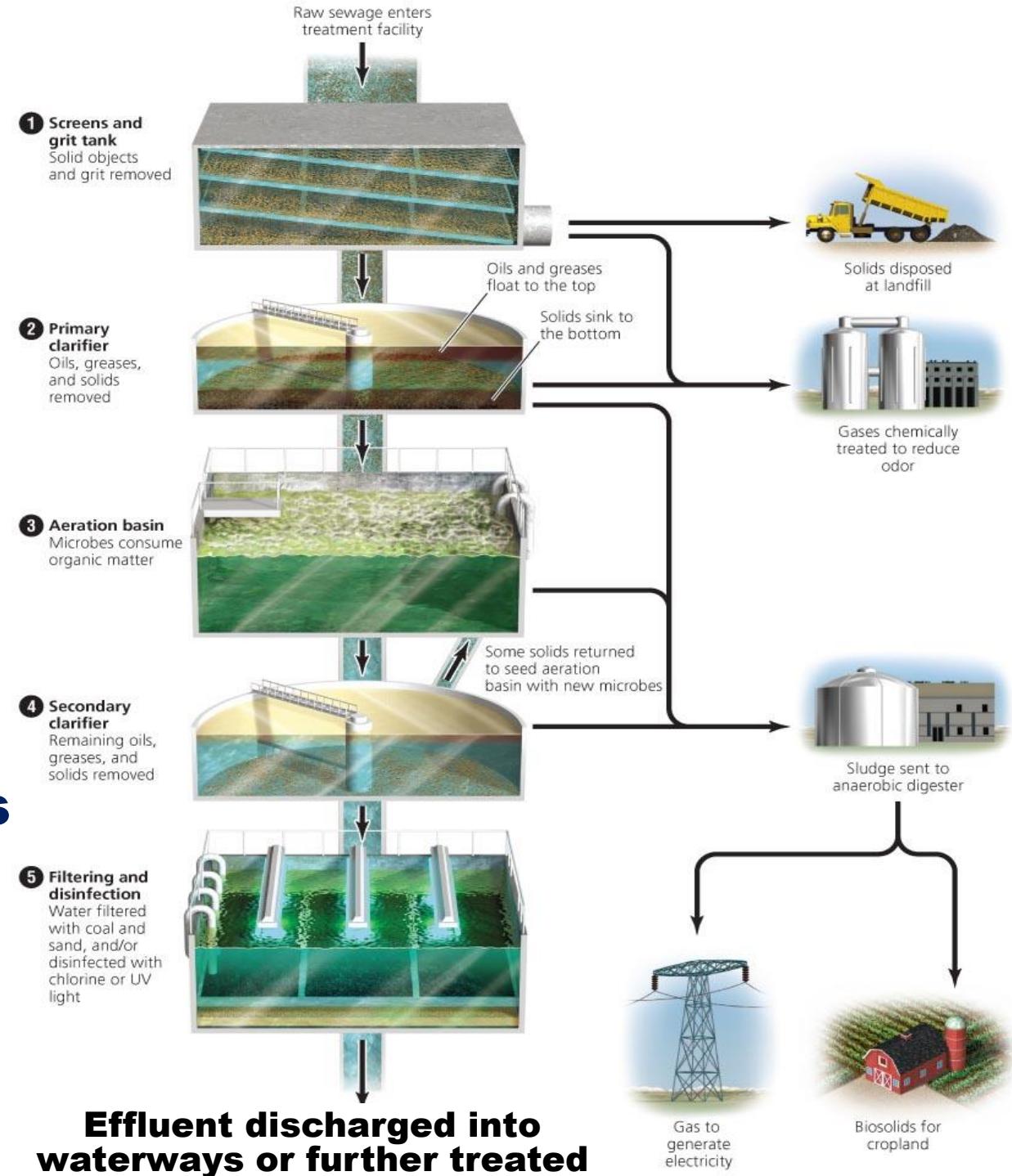
# Treating Wastewater

- **Primary treatment:** physically removes contaminants in settling tanks (clarifiers)
- **Secondary treatment:** water is stirred & aerated
  - Aerobic bacteria degrade organic pollutants
  - Water is treated with chlorine (&/or ultraviolet light, sometimes ammonia) & then piped into rivers or ocean or further cleaned & recycled
- **Reclaimed water:** treated & used for lawns, irrigation, industry, or to recharge aquifers
- Further treatment with reverse osmosis for drinking water



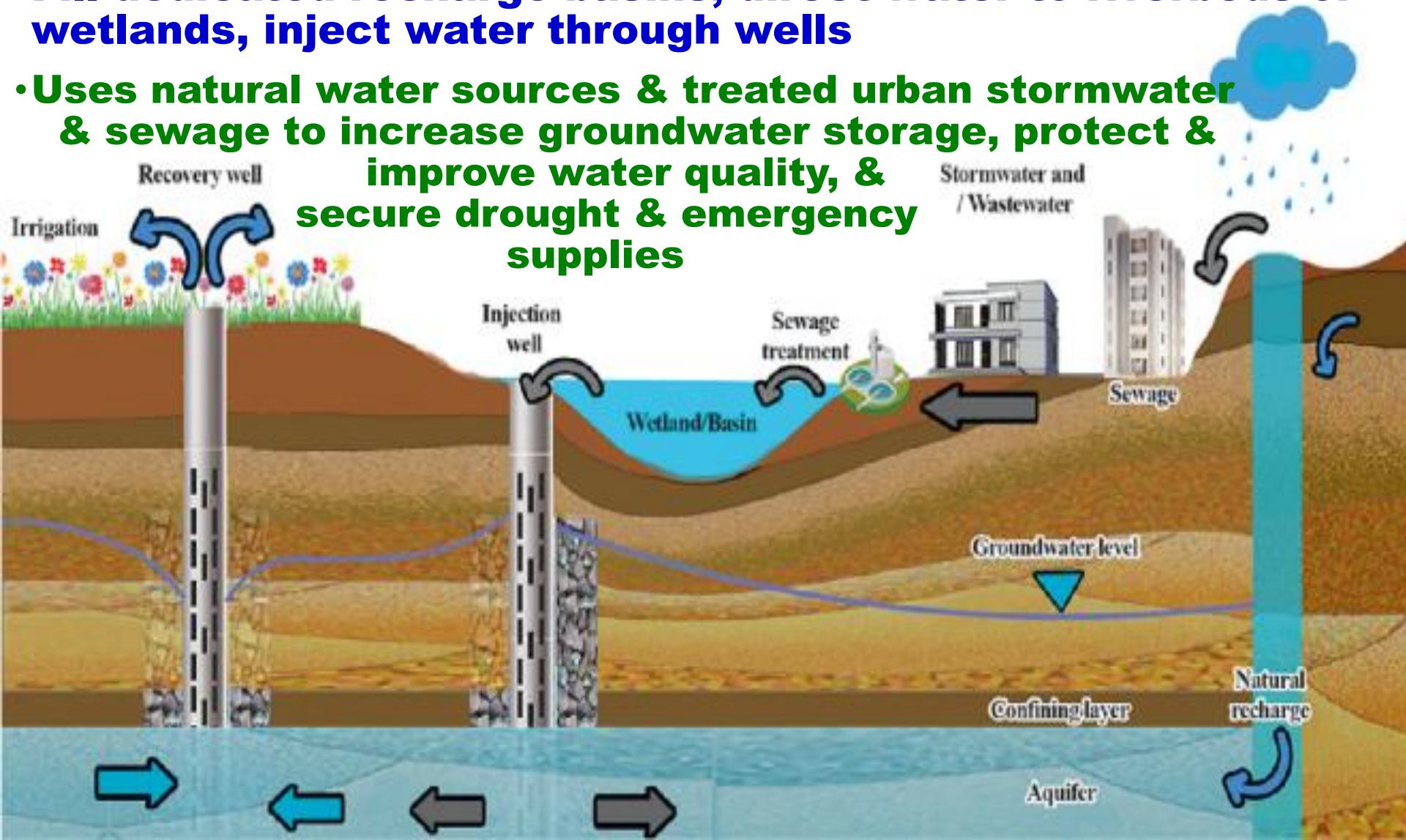
# Wastewater treatment facility

- **Sludge: leftover solid material is decomposed by microbes, then landfilled, incinerated, or used as fertilizer on cropland**
- **Methane-rich gas created by decomposition can be burned to generate electricity**



# Managed Aquifer Recharge

- Intentional recharge of water to aquifers for subsequent recovery or environmental benefit
- Fill dedicated recharge basins, direct water to riverbeds or wetlands, inject water through wells
- Uses natural water sources & treated urban stormwater & sewage to increase groundwater storage, protect & improve water quality, & secure drought & emergency supplies



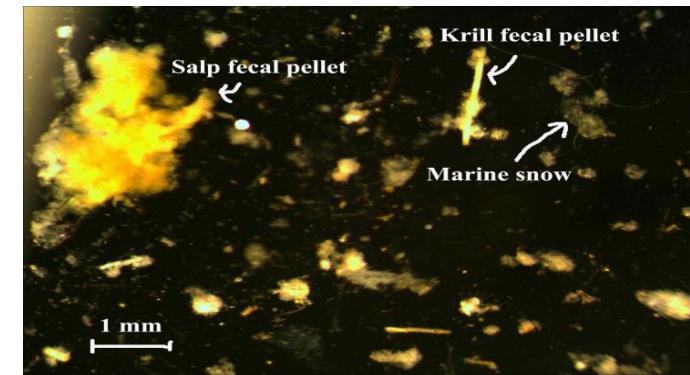
# **Ocean covers over 70% of Earth's surface**

- Contains 97.5% of Earth's water & produces 40-50% of oxygen we breathe (phytoplankton)
- Ocean influences climate (create many storms, coastal climates are milder & more humid), are rich in biodiversity, provide resources, aid in transportation & commerce
- Ocean influences the atmosphere, lithosphere, & biosphere

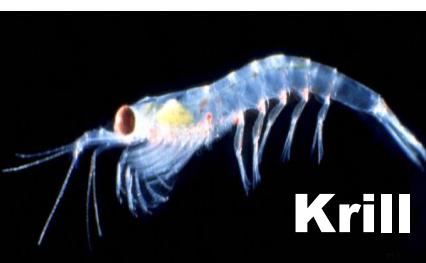


# Marine & coastal ecosystems

- Regions of ocean water differ greatly
  - Some zones support more life than others
- Photic zone = Sunlit top layer, 90% of species found here
  - Absorbs 80% of solar energy
  - Supports high primary productivity (phytoplankton at base of food web)
- Pelagic: open-water habitats between ocean surface & seafloor
- Benthic: habitats on the ocean floor
  - Organic detritus (poop, plant & animal remains) & carcasses from above provides major food source



# Open Ocean (Pelagic Zone): organisms swim or float in open water



Krill

Photic Zone  
(sunlit, surface)  
Species



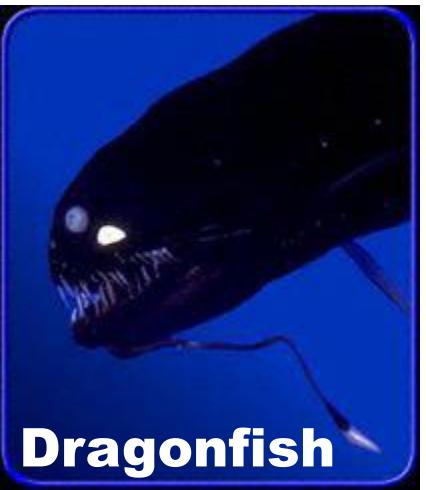
Yellowfin  
Tuna



Sharks

Aphotic zone (Little to No light)  
Many Bioluminescent species

~Produce their  
own light



Dragonfish

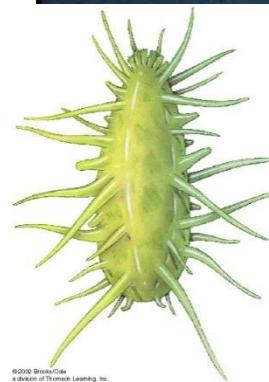
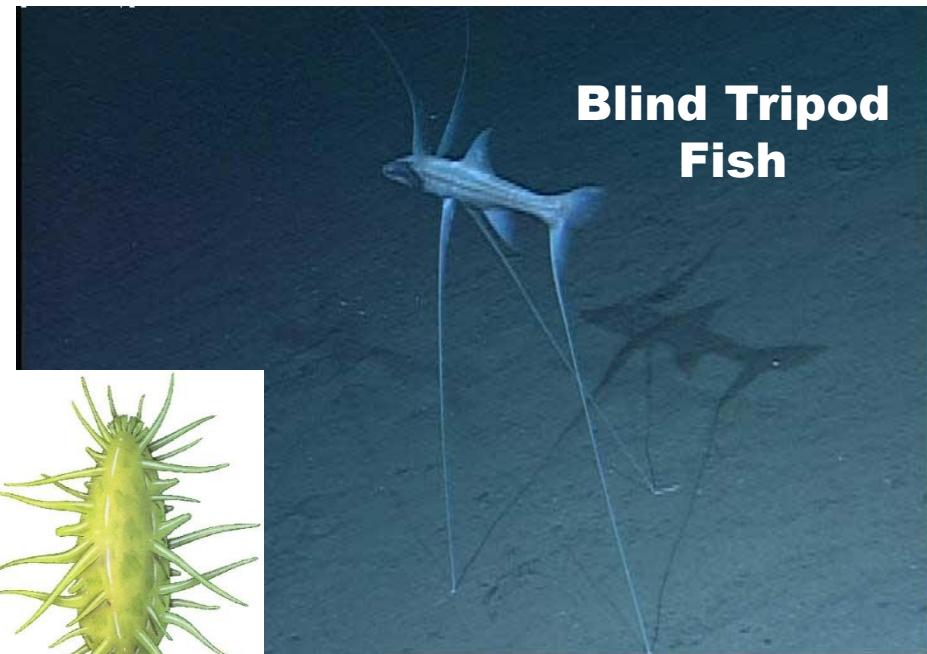


Anglerfish



Dolphin

# Deep Sea Floor: Always dark, usually cold, hypersaline & highly pressurized, yet many species are found in this harsh environment



# **Kelp forests harbor many organisms**

- Large, dense, brown algae growing from the floor of continental shelves of temperate zone coastal areas
  - Provide shelter & food for organisms (highly productive)
- Absorb wave energy & protect shorelines from erosion



**Intertidal Zone:** Where the ocean meets the land. Includes rocky tidepools & sandy beaches



A tough place to live

- Tidepools support amazing diversity with abundant food, nutrients, micro-habitats & niches
- Temperature, salinity, & moisture change dramatically from high to low tide
- Sandy intertidal zones have slightly less biodiversity

# **Coral reefs: greatest biodiversity on Earth**

- Consist of millions of tiny, colonial coral polyps – build reef with their skeletons
- Located in shallow, coastal, subtropical & tropical waters
- Protect shorelines by absorbing waves (tsunami, hurricanes)
- Innumerable invertebrates & fish species find food & shelter in reef



**Corals: tiny invertebrate animals**

**Get food from symbiotic algae (*zooxanthellae*)**

# Fresh & Salt water meet in Estuaries

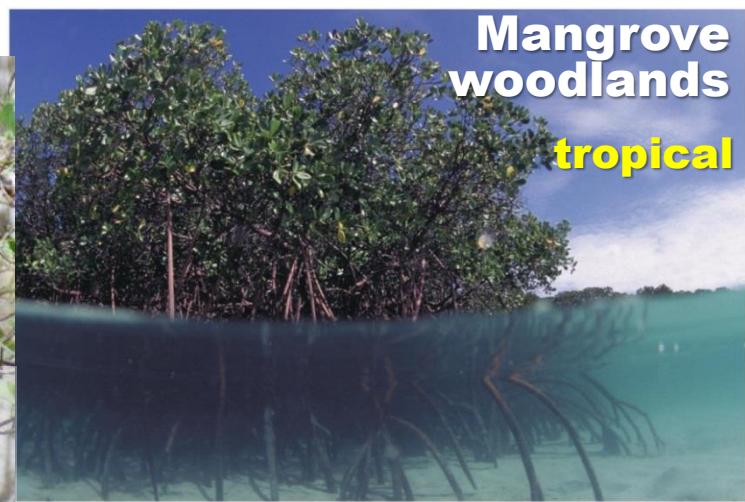
- Highly productive wetlands: comparable to coral reefs & tropical rain forests
- Critical wildlife habitat: Fish spawning areas & nurseries, bird nesting & migration
- Stabilize shorelines against flooding & storm surges, filter water pollutants, recharge aquifer
- Unappreciated - most filled in or polluted:
  - Urban development, harbors, power plants, agriculture, roads, heavily overfished



Salt marshes  
temperate



Monkeys  
use  
mangroves



Mangrove  
woodlands  
tropical

# Marine pollution

- People use oceans as a dump for waste and pollutants
- Even into the mid-20th century, coastal U.S. cities dumped trash & untreated sewage along their shores
  - Many other nations still do
- Nonpoint source pollution comes from all over
  - Oil, plastic, chemicals, excess nutrients, sediment



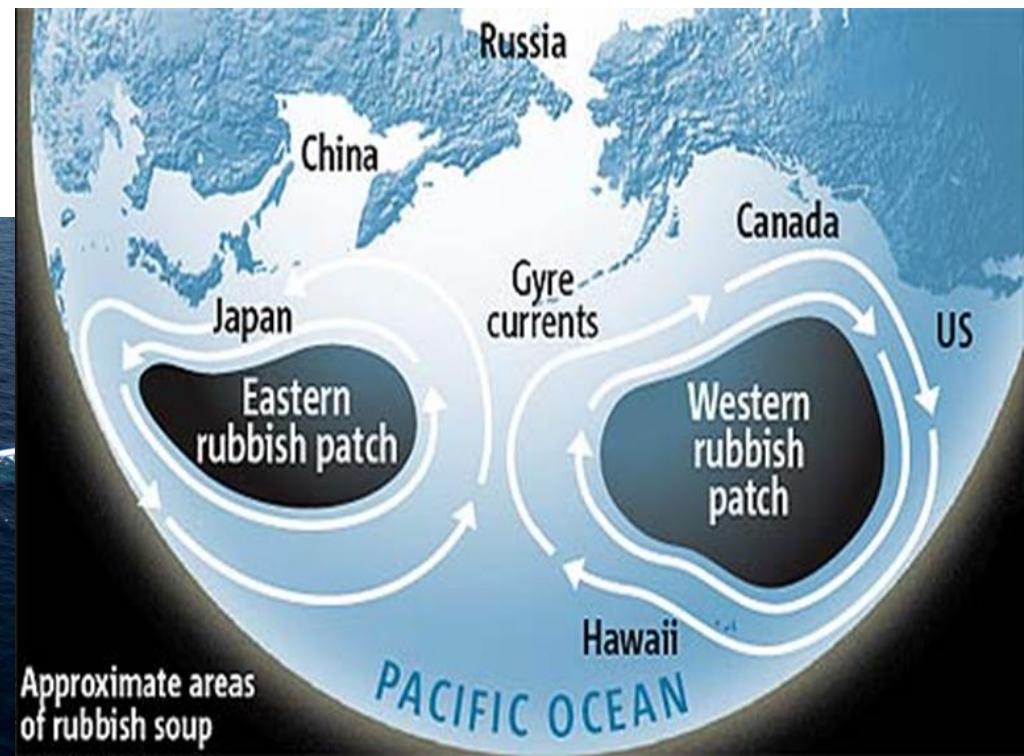
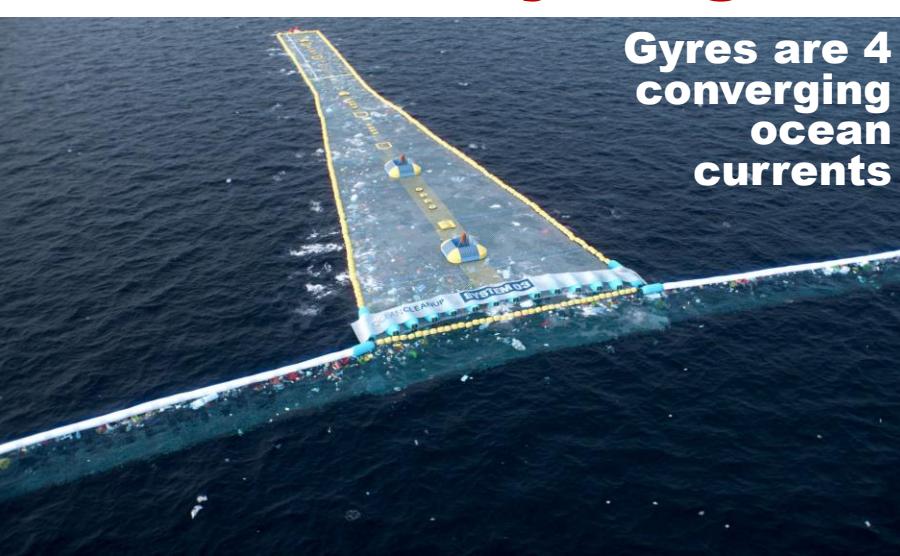
# Solid Waste.....“Just One Word, Plastics”

- Plastic on beaches increased >50% since 1994
- 46,000 plastic items per mi<sup>2</sup> over all of ocean
  - Breaks down SLOWLY, never disappears, just gets smaller, 61% of plastic in sea is <1 mm
  - Cigarettes #1 (lasts for 100's of years), food wrappers, bottles, bags, Styrofoam, caps, cutlery, straws – *From our disposable lifestyle*
- Animals get caught, or eat it & then toxic plastic enters OUR food chain



# Ocean Garbage Patches

- 8 million tons of plastic enters the ocean annually
- Found in all ocean gyres, largest patch in N. Pacific is 3X size of France
- Ocean plastic absorbs toxic chemicals (DDT, PCB), increasing their concentration by a million, which are eaten by fish & then us
- Boyan Slat & The Ocean Cleanup developed technology to collect plastic in gyres & rivers for recycling



# Reducing Ocean Plastic at the Source

- The Ocean Cleanup is cleaning up historic plastic in gyres, rivers, & along coasts
- But, we must also stop new plastic entering ecosystems
- Most plastic in the ocean originates from rivers that carry plastic from inland areas to the coast & from the fishing industry
  - Just 1,000 of the World's rivers carry 80% of plastics into the ocean
  - The Ocean Cleanup's River Interceptors stops new plastic from entering the ocean from rivers





**20 Interceptors deployed in 9 countries  
along with many other barrier technologies**



**Interceptor in Ballona Creek in Los Angeles**



# Reducing Plastic Pollution



- Plastics slowly break down into smaller toxic, bits (plastic bottle ~1,000 yrs.)
- Each year: ~1 trillion plastic bags used worldwide, 30-40 billion bottles thrown away(U.S.A)
  - Only 9% of plastic is recycled
- Many cities (Mexico City, Delhi) & countries (Netherlands, Bangladesh) ban or tax plastic bags. CA bans plastic grocery bags (2016 & 2025) & polystyrene (2026)
- Ireland's 34¢ tax decreased bag use by 95%





But, we ALL must also reduce  
use of plastic from manufacturers  
to consumers



Wealthy communities use  
more disposable products



Expensive,  
produces  
more waste

# What Can You Do?

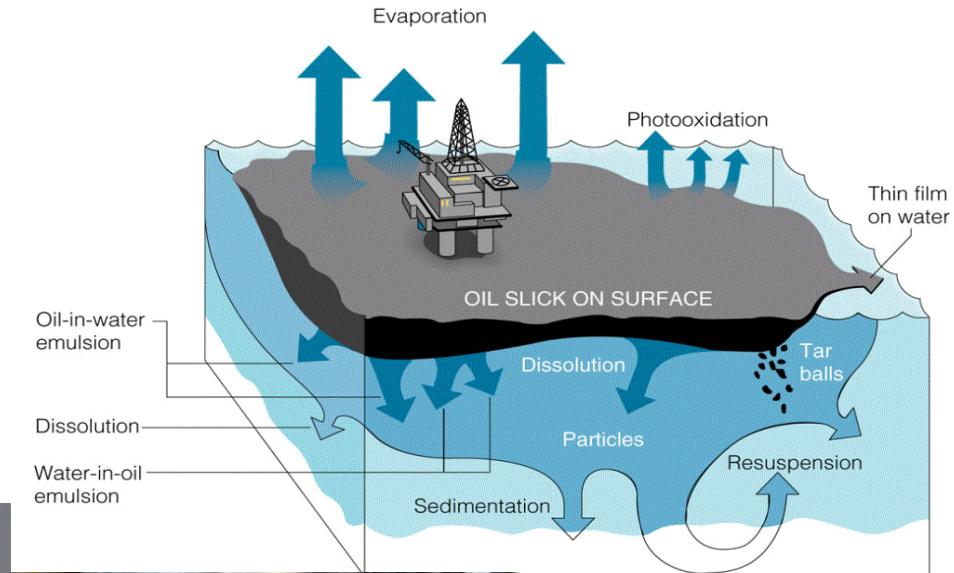
Ch. 17

1. **RECYCLE!** California recycling is one of the best in the world, but we ALL must reduce plastic use:
2. **Carry reusable bottle, bag, fork/spoon**
3. **Refuse plastic straws, lids, utensils**
4. **Choose products in glass or metal & recycle them**
5. **Eat in restaurants instead of taking to go**
6. **Buy products with less packaging (no bagged apples, tea in plastic packets)**
7. **Use razors with replaceable blades**
8. **Use toothbrush with replaceable head or bamboo ones**
9. **Buy concentrated cleaners (smaller package)**
10. **Eat in restaurants instead of taking to go**
11. **Buy fewer, higher quality clothes that last longer or shop second hand**



# **Oil pollution**

- 30% of oil comes from seafloor deposits that are drilled & extracted
- Spills from drilling or damaged tankers harm species & ecosystems, valuable fisheries, tourism, economies



**Largest accidental spill in world history (4.9 million barrels = 206 million gallons)**

# Gulf Oil Spill Flowed for 120 Days

- NOAA estimates: **1/4 removed, 1/4 evaporated or dissolved, 1/4 dispersed as small toxic droplets**
- Last 1/4 of oil was left as **oil slicks on water, tar balls on beaches, sunk to seafloor**



- Oil clogs fish gills, coats mammal fur & bird feathers, losing buoyancy & insulation



Orange Beach, Alabama, covered in oil

Oil on shoreline	Oil on water surface
● Very light	■ 1–10 days
● Light	■ 10–30 days
● Medium	■ More than 30 days
● Heavy	

# **Oil Clean-up**

- **Booms contain**
- **Dispersants (soap) to break it up, but can damage corals, sea grasses, & accumulate in seafood**
- **Skimmers & absorbent materials mop it up**
- **Burn it, shovel it, oil-digesting bacteria & sunlight degrade it**

**Washing oiled animals with dish soap**



**Booms keep oil from shore**



**Salons send hair to volunteers who use it to make booms & mats that absorb oil**



**Boat distributes dispersant**

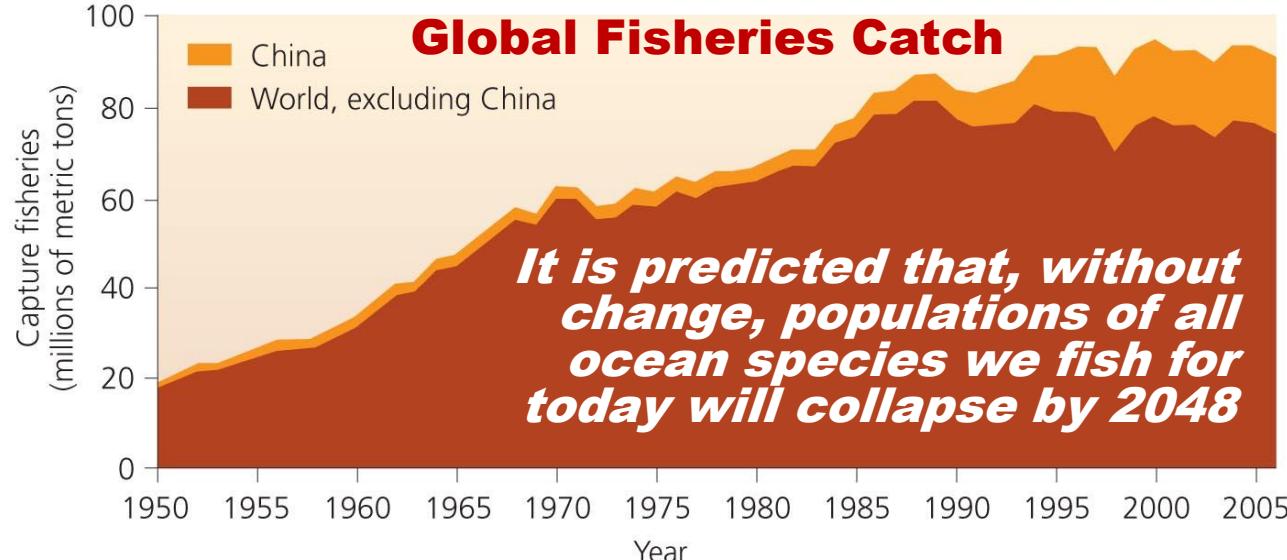


**Skimmers collect oil**



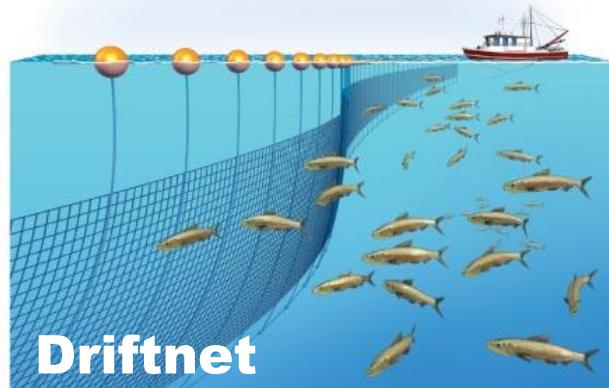
# Emptying the oceans through overharvest

- One of the worst marine problems
- 50% of world's marine fish populations are fully exploited & can't be fished more intensively, 28% are heading to extinction
  - Populations of large fish (tuna, sharks...) have decreased by 90%
- Total fisheries catch leveled off after 1988, despite increased fishing effort
- Maximum wild fisheries potential has been reached



# Fishing has industrialized

- **Factory fishing:** huge vessels use powerful technologies to capture fish in immense volumes
  - Even process, can, freeze at sea
- Fishing practices kill non-target species accidentally in nets or longlines (**bycatch**)
- Small or low-value fish, turtles, sharks, dolphins, seals, seabirds



**Driftnet**

Schools of herring, sardines, mackerel, sharks, shrimp



**Longline fishing for tuna & swordfish**



**Trawling for pelagic fish & groundfish**

(c) Bottom-trawling

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# Consumer Choices

- Consumers impact the health & survival of marine species
- Choose well-managed, harvested & farmed species
  - Alaskan, Icelandic, New Zealand fisheries
  - Marine Stewardship Council (MSC) Certified
- Eat lower on food chain (Large tuna species eat 15,000 small fish/year), tilapia are herbivores
- Monterey Bay Aquarium's Seafood Watch



The image shows two screenshots of the Monterey Bay Aquarium Seafood Watch website. The left screenshot displays the homepage with a large "Seafood WATCH" logo and a "Choices for Healthy Oceans" section. The right screenshot shows a detailed page for Salmon, featuring a large image of a salmon, a "Market Overview" table, and sections for "Salmon, wild-caught and farmed" and "Salmon, wild-caught and canned".

Nonprofit groups have guides to aid consumer purchases

A collage of Seafood Watch guides and cards. It includes a large "Seafood WATCH" booklet titled "Choices for Healthy Oceans", several smaller cards such as "How to Read Seafood Watch Cards", "Seafood WATCH Quick Guide", and "Seafood WATCH Card", and a "Seafood WATCH App" icon.

# How to add Seafood Watch to your home screen

## Android

1. Launch Chrome for Android, and open SeafoodWatch.org.
2. Tap the browser's menu button (3 vertical dots) at the top right part of the screen. Select 'Add to home screen' or 'Install app'.
3. You can edit the name of the shortcut, if you'd like, then tap Add. Chrome will add the icon to your home screen. You can now drag the icon around and place it where you prefer — just like a normal app icon.
4. To access Seafood Watch recommendations, simply search the name of the species you're looking for or tap the 'Browse all' link.

## iPhone and iPad

1. Launch the Safari browser on Apple's iOS and navigate to SeafoodWatch.org.
2. Tap the share button (the square with an upwards pointing arrow) at the bottom of the screen and choose 'Add to home screen'.
3. You can edit the name of the shortcut before tapping the add button. The icon has been added to your home screen. You can now drag the icon around and place it where you prefer — just like a normal app icon.
4. To access Seafood Watch recommendations, simply search the name of the species you're looking for or tap the 'Browse all' link.

**Tip:** Does the full recommendations database make your head swim? You can quickly access our seafood buying guides by clicking the fish icon in the upper right-hand corner of the mobile website, next to the magnifying glass search bar icon.

# Fisheries management

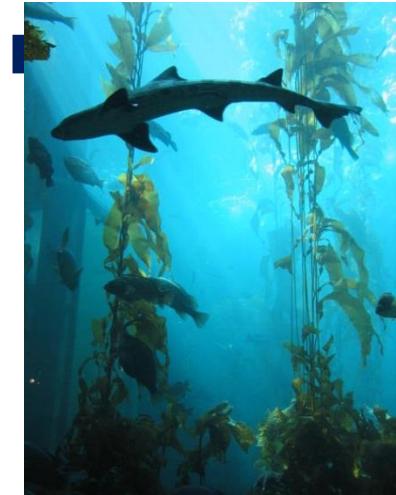
- Properly managed fisheries can be renewable resources
- Based on maximum sustainable yield to maximize harvest
  - While keeping fish available for the future
  - Managers may limit the harvest or restrict gear used
- Protect breeding grounds & set aside areas of oceans free from human interference
- Marine protected areas (MPAs) allow limited amount of fishing or other extractive activities
- Marine reserves prohibit fishing inside of reserves: Density of organisms increased 91%, organism size increased 31%, species diversity increased 23%



Consider  
other species  
dependent on  
fish stocks

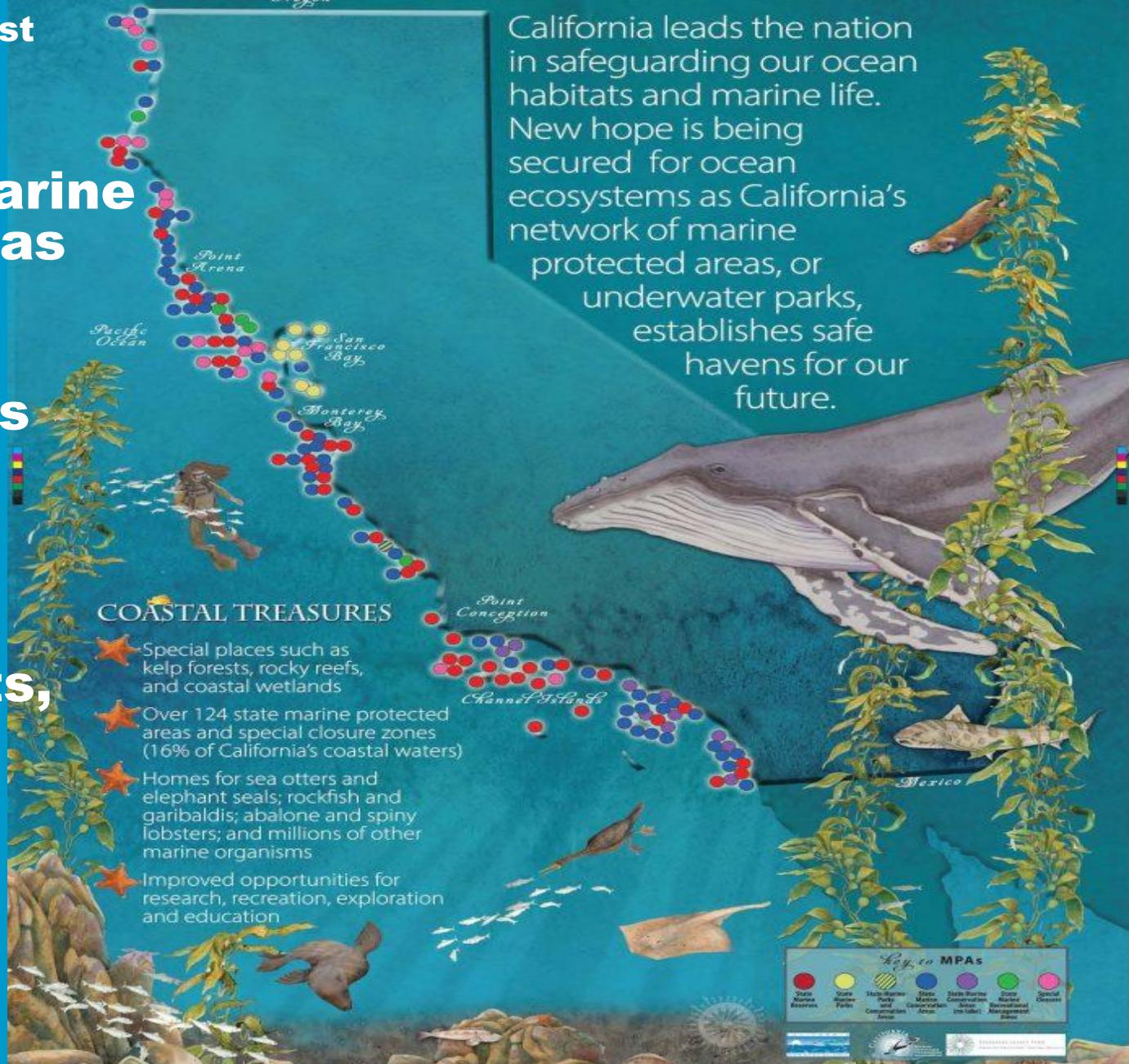
# Areas outside reserves also benefit

- A “spillover effect” occurs when individuals of protected species spread outside reserves
  - Larvae of species protected within reserves “seed the seas” outside reserves
  - Improves fishing & ecotourism
- Local residents who were opposed support reserves once they see their benefits

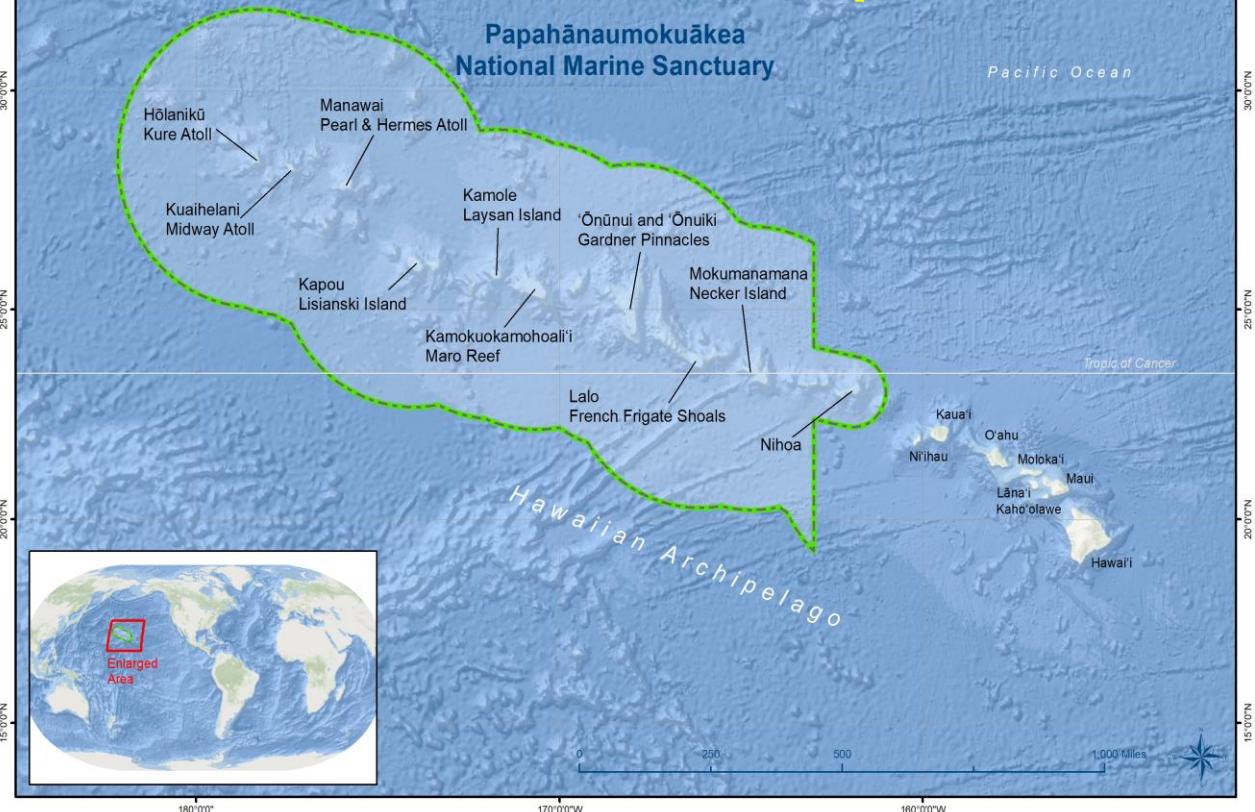


- In 2012, California became the 1<sup>st</sup> state in USA to establish a network of marine protected areas (MPAs)
- Similar to National Parks & Forests on land
- Protects & restores ocean habitats, & increases the health, productivity & resilience of ocean ecosystems

# TURNING THE TIDE CALIFORNIA'S UNDERWATER PARKS



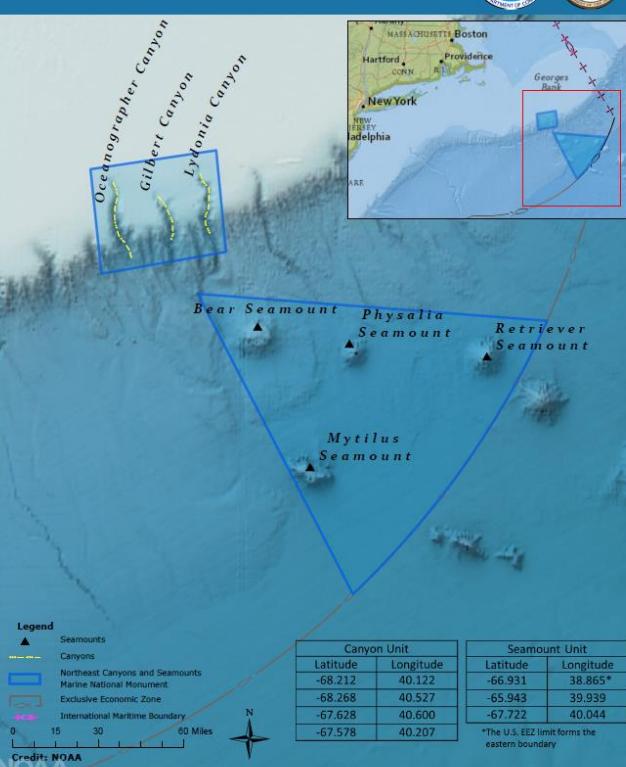
**1st Established as a Marine National Monument in 2006 & expanded in 2016**



**In 2025 Papahānaumokuākea became a USA's 18<sup>th</sup> Marine National Sanctuary**

**The biggest protected area on Earth at 582,578 square miles (1,508,870 km<sup>2</sup>)**

**Northeast Canyons and Seamounts Marine National Monument**



**1st Atlantic Ocean Marine National Monument created in 2016:**

**4,913 mi<sup>2</sup> of Submarine Canyons & Seamounts**

