Purposes of Chemical, Physical, and Biological Monitoring

General Purposes

- Assess use attainment
- Characterize watershed
- Identify pollutants and sources
- Investigate fate & transport
- Measure effectiveness
- Determine changes and trends
- Assess compliance
- Modeling

Our Focus

- Assessment
  - Problems
  - Causes
  - Sources

Indiana Water Quality Assessment

- State : 5 major water management basins
- Monitoring: 5-year rotation through basins
  - Watershed monitoring program
  - Fixed station monitoring program
  - E. coli monitoring program
  - Fish community program
  - Fish tissue contaminant program
  - Macroinvertebrate community program
  - Special projects
  - Clean Lakes program

http://www.in.gov/idem/programs/water/303d/idem_calm.doc

Indiana Water Quality Assessment

- Designated Uses
  - All waters (unless exempted) to support full body contact recreation and protect aquatic life, wildlife, & human health
  - Fish consumption, drinking water supply
- Assessment methodology
  - USEPA guidelines for 305(b) and 303(d)
- Assessment units
  - 14-digit HUAs (5,000 to 20,000 acres in IN) or finer
  - Lakes, reservoirs, wetlands tracked individually

http://www.in.gov/idem/programs/water/303d/idem_calm.doc

Indiana Water Quality Assessment

- Comprehensive assessment for each AU using assessments from each monitoring program
- Assessment for each designated use
- Use support criteria address a range of chemical, physical, and biological variables, including:
  - Nutrients (new criteria for recreational use support in lakes and reservoirs – aesthetics)
  - D.O., pH, total dissolved solids, sulfates, chlorides
  - Macroinvertebrates, fish, habitat, bacteria (E. coli)
  - Metals, pesticides, PCBs, other toxicants

http://www.in.gov/idem/programs/water/303d/idem_calm.doc

Chemical

USGS

Pros & Cons

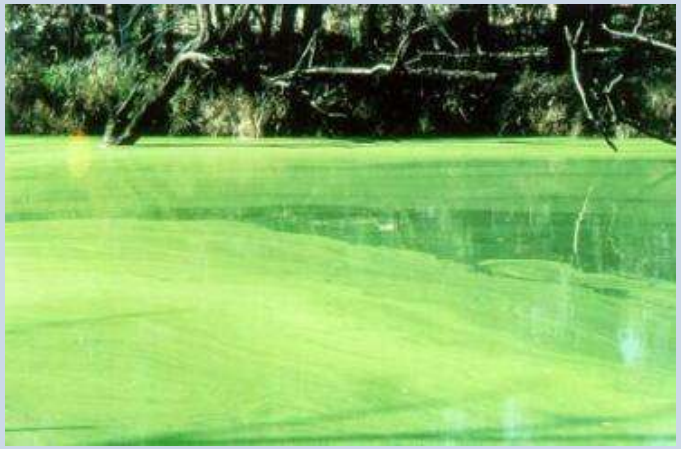
Chemical and Physical

- Quantitative, real number
- Sample collection and analysis usually straightforward
- Directly related to water quality criteria, project goals

- Represent only instantaneous conditions
- Consider only one parameter at a time
- May be difficult to relate to use, public perception

Phosphorus

- Nutrient for plants
- Usually limiting (vs. N) in fresh waters
- Slight increase can cause accelerated eutrophication
  - Accelerated plant growth
  - Algae blooms
  - Low dissolved oxygen (hypoxia)
  - Fish kills



Phosphorus Sources

- Soil and rocks
- Wastewater treatment plants
- Runoff from fertilized lawns and cropland
- Failing septic systems
- Runoff from animal manure storage areas
- Commercial cleaning preparations

Nitrogen

- Nitrate (NO3), ammonia (NH3), nitrite (NO2), organic N
- Nitrate is readily available plant nutrient
- If sufficient P, accelerated eutrophication
- Toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher) under certain conditions
- Ammonium toxicity

Nitrogen Sources

- Wastewater treatment plants
- Runoff from fertilized lawns and cropland
- Failing on-site septic systems
- Runoff from animal manure storage areas
- Industrial discharges that contain corrosion inhibitors
- Air deposition

Total Solids

- Total solids are dissolved solids plus suspended and settleable solids in water
- Dissolved solids = calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other ions and particles that will pass through a 2 micron filter
- Suspended solids = silt, clay, plankton, algae, fine organic debris, and other particulate matter that will not pass through a 2-micron filter

Effects of Total Solids

- Water balance in cells of aquatic organisms
  - Sink or float due to cell density
  - Survival risk
- Carriers of adsorbed toxics (e.g., pesticides)
- Clog irrigation devices
- Deposition in waterbodies
- High total solids levels foul drinking water
- Efficiency of wastewater treatment plants and the operation of industrial processes
- Reduces water clarity and photosynthesis

Total Solids Sources

- Industrial discharges
- Sewage
- Fertilizers
- Road runoff
- Soil erosion

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Conductivity

- Indicates chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron, and aluminum ions
- Increases with water temperature

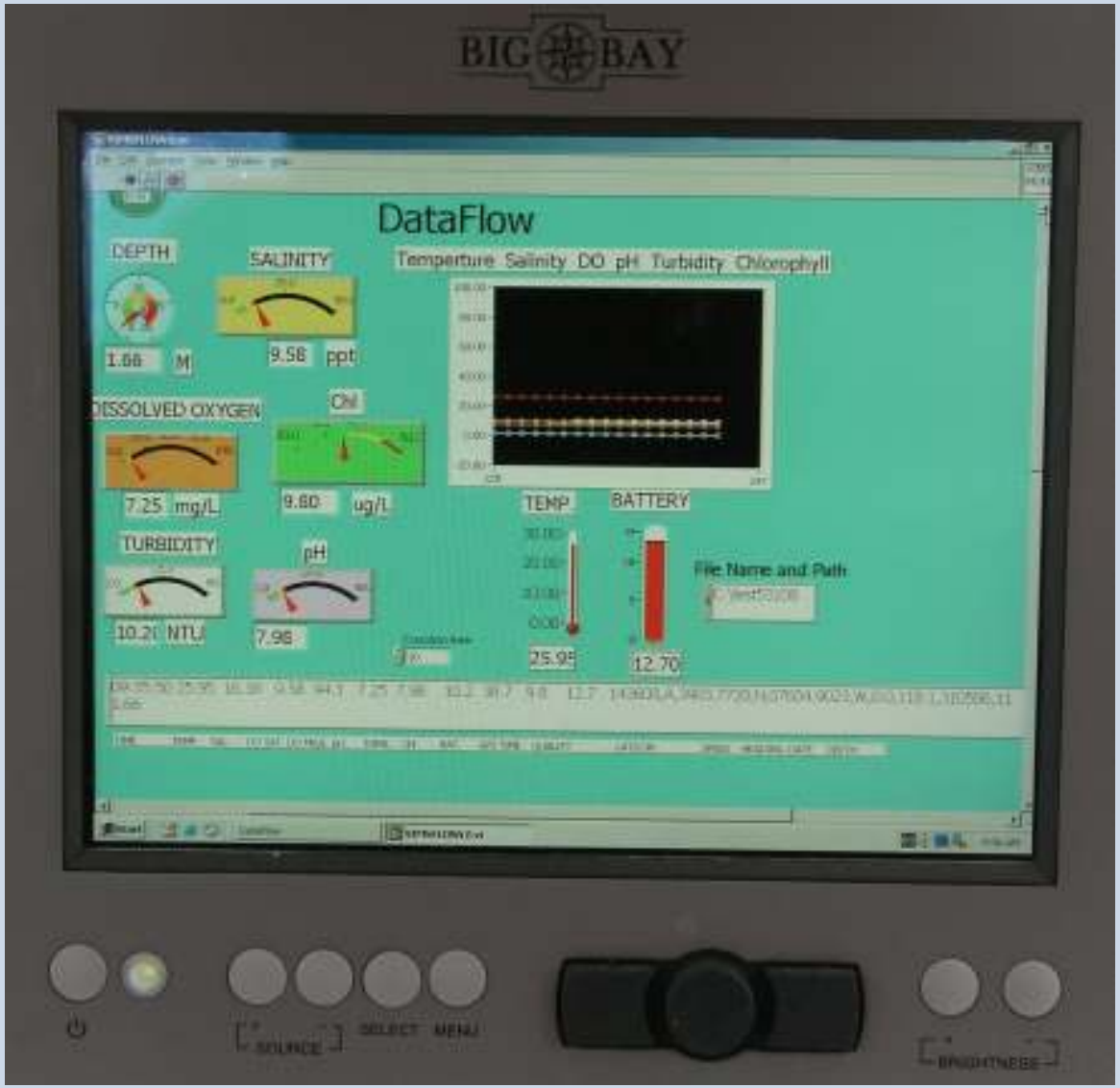
Conductivity Sources

- Sources of dissolved solids, N, P
- Geology
  - Granite bedrock – lower conductivity
  - Clay soils – higher conductivity
- Groundwater inflow

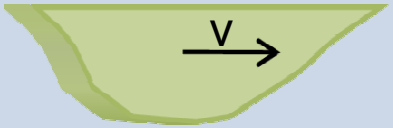
Alkalinity

- Measures capacity to neutralize acids from rainfall or wastewater
- Constituents: bicarbonates, carbonates, and hydroxides
- Sources: rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges

Physical


BIG BAY
DataFlow
DEPTH
SALINITY
Temperture Salinity DO pH Turbidity Chlorophyll
1.66 M
9.58 ppt
DISSOLVED OXYGEN
CHl
7.25 mg/L
9.80 ug/L
TEMP
BATTERY
TURBIDITY
pH
File Name and Path
10.20 NTU
7.98
25.95
12.70
SOURCE
SELECT
MENU
BRIGHTNESS

Stream Flow



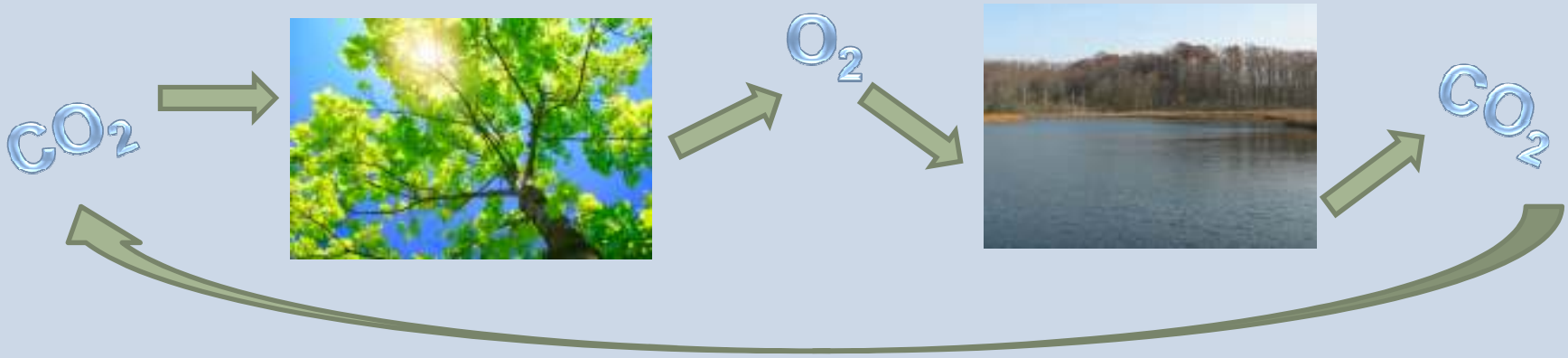
- Stream flow (discharge) = the volume of water that moves over a designated point over a fixed period of time
- Flow = Area · Velocity
- Affected by weather, season, withdrawals, and dams
- Greater flow and velocity = greater pollutant assimilative capacity
- Stream velocity determines:
  - Species of organisms that can live in the stream
  - The amount of silt and sediment carried by the stream
  - Dissolved oxygen level in stream

Dissolved Oxygen

- Dissolved oxygen (DO) is oxygen dissolved in the stream water
- DO levels influence animal species that live in waterbodies
  - Most vulnerable to lowered DO levels in early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset
- DO levels vary:
  - Seasonally
  - Diurnally (over a 24-hour period)
  - Inversely with water temperature and altitude

D.O. Inputs and Consumption

- Oxygen inputs: atmosphere, plant photosynthesis, riffles
- Oxygen consumption: respiration, decomposition, & various chemical reactions
  - Wastewater from sewage treatment plants
  - Stormwater runoff from farmland or urban streets, feedlots, and failing septic systems.



Biochemical Oxygen Demand (BOD)

- BOD = the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water
  - Also measures the chemical oxidation of inorganic matter (i.e., the extraction of oxygen from water via chemical reaction)
  - Affected by: temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and inorganic material in the water
- DO = f(BOD)
  - High BOD lowers DO
  - Aquatic organisms become stressed, suffocate, and die

Photo: University of New Hampshire

BOD Sources

- Leaves and woody debris
- Dead plants and animals
- Animal manure
- Effluents from pulp and paper mills, WWTPs, feedlots, and food-processing plants
- Failing septic systems
- Urban stormwater runoff

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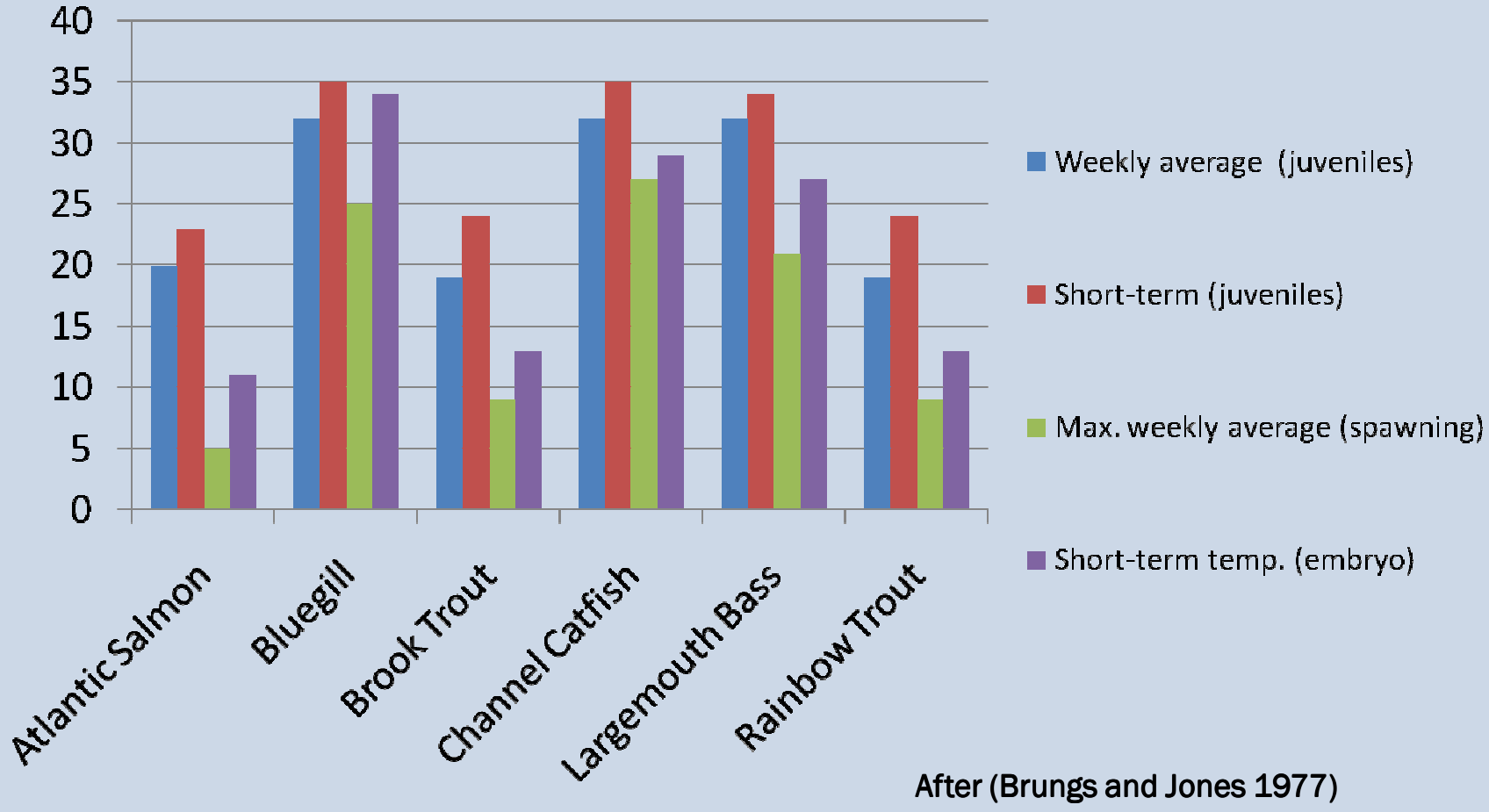
Water Temperature

- Rates of biological and chemical processes depend on temperature
  - Rate of photosynthesis by aquatic plants
  - Metabolic rates of aquatic organisms
  - Sensitivity of organisms to toxic wastes, parasites, and diseases
- Temperature range determines species composition
  - Fish limited by:
    - Maximum temperature for short exposures
    - Weekly average temperature
  - Varies by time of year and life cycle stage
    - Reproductive stages (spawning and embryo development) are the most sensitive stages

Maximum average temperatures for growth and short-term maximum temperatures for selected fish (°C)



After (Brungs and Jones 1977)

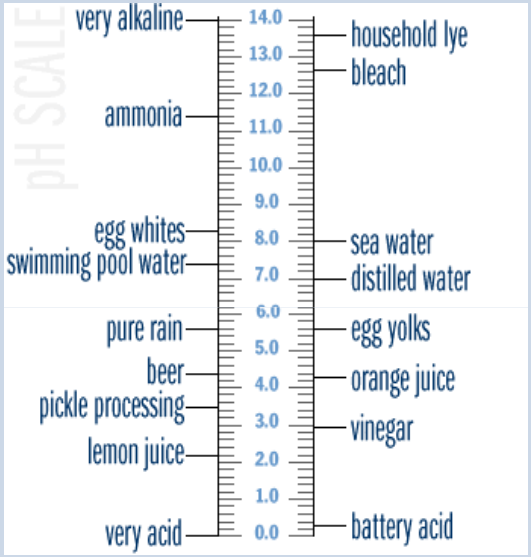
Causes of Temperature Change

- Weather
- Removal of shading streambank vegetation
- Impoundments
- Discharge of cooling water
- Urban storm water
- Groundwater inflows to the stream

www.diverdan.net

pH

- pH range of 1 (strong acid) to 14 (strong base)
  - Base 10 logarithmic scale (pH of 2 is 10 times as acidic as pH of 3)
- pH affects many chemical and biological processes
  - Preferred range generally 6.5-8.0
  - Diversity decreases outside this range
    - Stress to physiological systems of most organisms
    - Reduced reproduction
    - Low pH can cause release of toxic elements (e.g., Cd) for uptake by aquatic plants and animals
  - Causes of pH change include acid rain, surrounding rock, and certain wastewater discharges

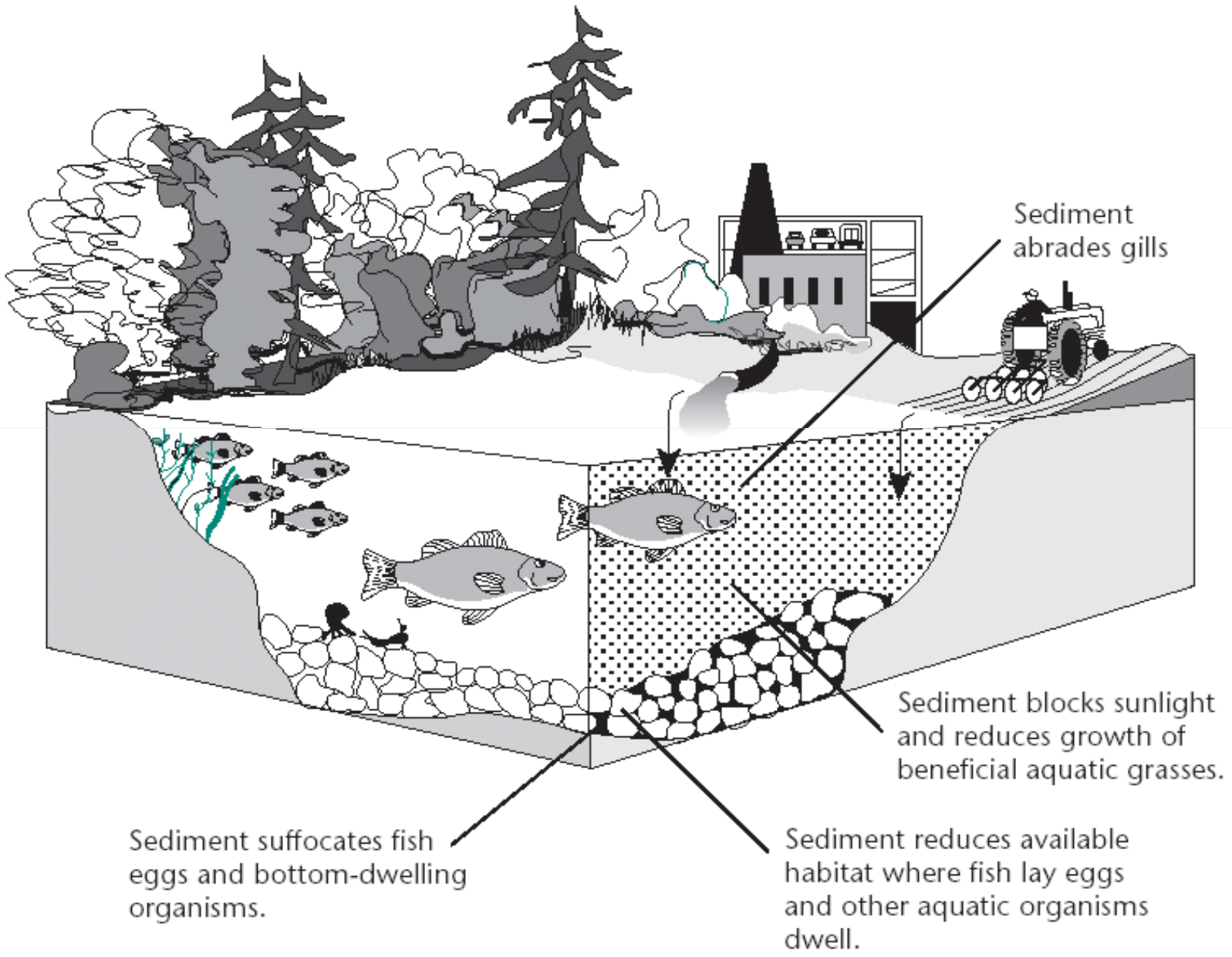


Turbidity

- Measure of water clarity
- Causes of turbidity:
  - Suspended clay, silt, sand
  - Algae, plankton, microbes, and other substances
- Effects of increased turbidity
  - Increased water temperature
  - Lower DO
  - Reduced photosynthesis and DO production
  - Clogged of fish gills
    - Reduced resistance to disease
    - Lower growth rates
    - Impaired egg and larval development
  - Deposition of settled particles
    - Smothered fish eggs and benthic macroinvertebrates

Indiana.edu

The Effects of Siltation in Rivers and Streams



Turbidity Sources

- Sources of turbidity include:
  - Soil erosion
  - Waste discharge
  - Urban runoff
  - Eroding stream banks
  - Large numbers of bottom feeders such as carp that stir up bottom sediments
  - Excessive algal growth

lwcd.org

Biological

www.samford.edu

Pros & Cons

Biological

- Organisms integrate effects of stressors over time
- Indicate real ecological issues
- Status of biological communities of direct public interest
- May be inexpensive relative to complex chemical tests

- High variability may make detection of change or trends difficult
- Specific pollutants or sources causing impacts may not be revealed
- Complex relationships with habitat, bioregion
- Collection may be inexpensive, but analysis may be expensive and time-consuming

Biological Monitoring

- Fish
- Habitat
- Algae
- Benthic macroinvertebrates
  - insects in their larval or nymph form, crayfish, clams, snails, and worms)

Biological Monitoring

- Determine support of aquatic life uses
  - Biological criteria
    - Benthic macroinvertebrate diversity and abundance impacted by stream biological, chemical, and physical conditions
    - Varying tolerance
      - Stonefly nymphs are very sensitive to DO
      - If no stoneflies, check DO
  - Biological surveys

Biological Monitoring

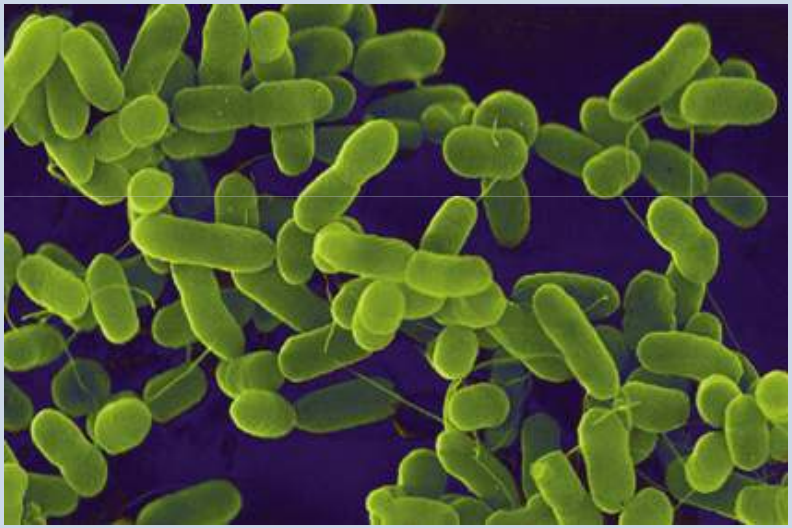
- Determine the severity of the pollution problem and to rank stream sites
  - Monitored stream data compared to data from reference site
- Characterize the impact of pollution and of pollution control activities
  - Identify problem sites along a stream

Fecal Contamination

- Coliforms and fecal streptococci used as indicators of possible sewage contamination because they are commonly found in human and animal feces
  - Generally not harmful themselves
  - Cheaper and easier to test than other pathogens
  - Indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans
    - Impaired swimming
    - Unsafe shellfish
    - Unpleasant odors
    - Increased BOD

Fecal Bacteria Indicators

- The most commonly tested fecal bacteria indicators are
  - Total coliforms
  - Fecal coliforms
  - *Escherichia coli*
  - Fecal streptococci
  - Enterococci



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Total Coliform

- A widespread group of bacteria
- Human feces, animal manure, soil, and submerged wood, etc.
- Utility as an indicator of fecal contamination depends on extent to which the bacteria species found are fecal and human in origin
- Not recommended for recreational waters
- Still standard test for drinking water

Fecal Coliforms

- A more fecal-specific subset of total coliform bacteria
  - Contains a genus, *Klebsiella*, with species that are not necessarily fecal in origin
    - Commonly associated with textile and pulp and paper mill wastes
  - Recently replaced by *E. coli* and enterococci as the primary bacteria indicator for recreational waters in many states

Escherichia coli

- *E. coli* is a single species in the fecal coliform group
  - Specific to fecal material from humans and other warm-blooded animals
- Best indicator of health risk in fresh water contact recreation along with enterococci
- Indiana uses E. coli for determining recreational use support (swimming)

Fecal Streptococci

- Digestive systems of humans and other warm-blooded animals
- FS were monitored with FC
  - FC/FS ratio was used to determine whether the contamination was of human or nonhuman origin
  - No longer recommended as a reliable test

Enterococci

- A subgroup of FS
- Can survive in salt water
  - More closely mimic many pathogens
  - Typically more human-specific than the larger fecal streptococcus group
  - EPA recommends enterococci as the best indicator of health risk in salt water used for recreation and as a useful indicator in fresh water as well

Sources of Fecal Contamination

- Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff

z.about.com

wdfw.wa.gov

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