Environmental, Aquatic Risk Assessment

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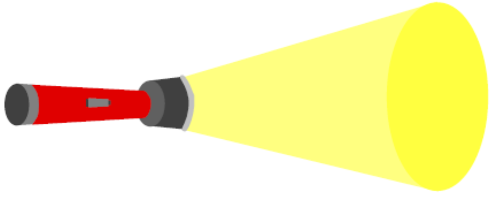
- **Aquatic risk assessment: the link between toxicology and public health.**

- **"*What is there that is not a poison? All things are poison...*". If all substances are potentially toxic, and if toxicity depends on dose, there must always be a "toxicity threshold"; in other words, a limiting dose below which a substance is no longer a "poison".**

- **Risk assessment has concentrated primarily on human health effects. To assess the risks arising from human exposure to a given substance, they attempt to establish the lower limits of toxicity.**

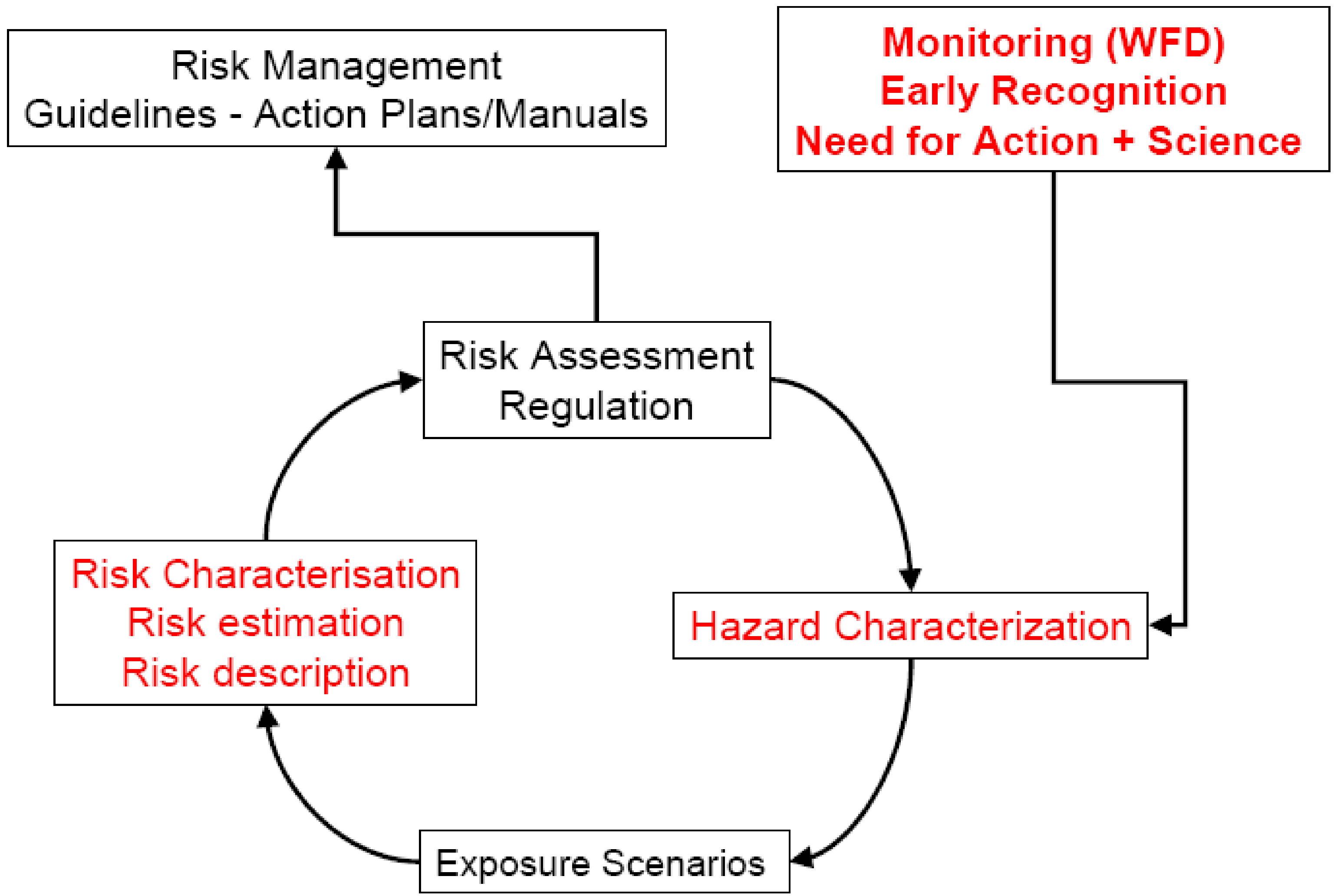
- **Risk assessment is the process of enumerating risks, determining their classifications, assigning probability and impact scores, and associating controls with each risk.**

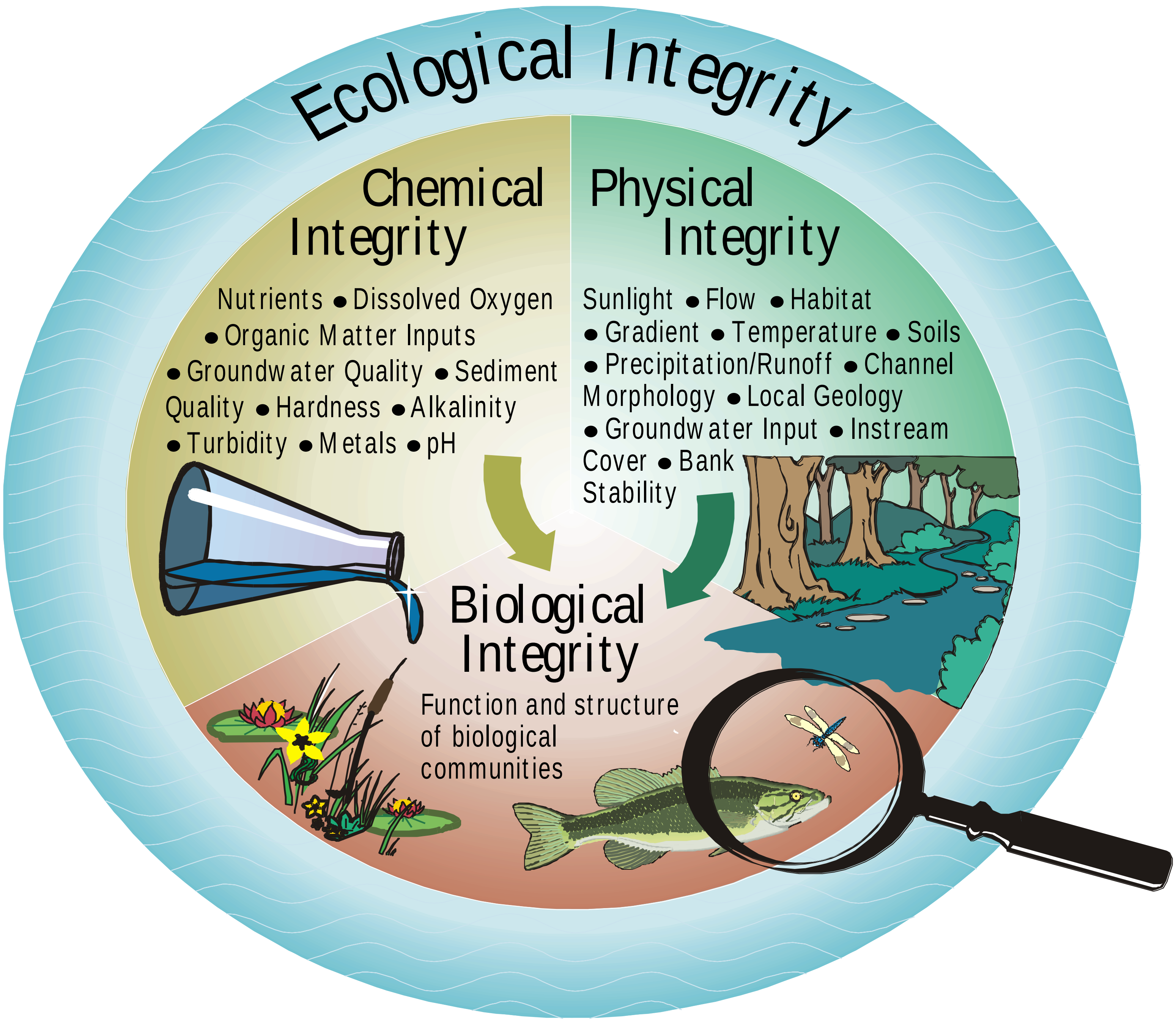


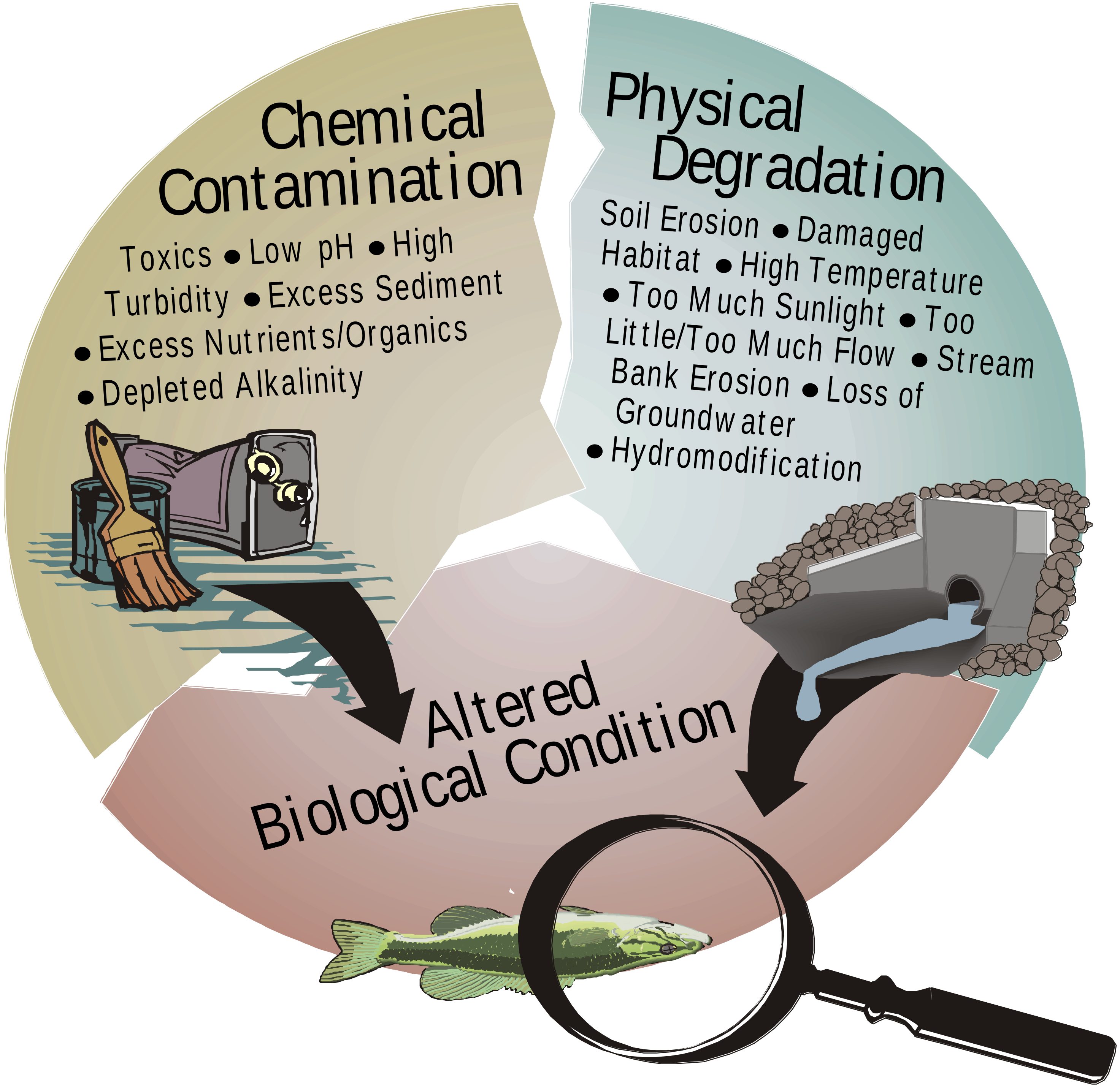
- **Ecological risk assessment and human health risk assessment ask the same questions:-**

- **Is there a problem? <u>(problem formulation)</u>**
- **What is the nature of the problem? <u>(characterization of exposure and characterization of ecological effects)</u>**
- **How can we summarize and explain the problem? <u>(risk characterization)</u>**
- **What can we do about it? <u>(risk management)</u>**

"Effective health and safety management is not 'common sense' but is based on a common understanding of risks and how to control them brought about through good management."


Risk Management
Guidelines - Action Plans/Manuals
Monitoring (WFD)
Early Recognition
Need for Action + Science
Risk Assessment
Regulation
Risk Characterisation
Risk estimation
Risk description
Hazard Characterization
Exposure Scenarios


Ecological Integrity
Chemical Integrity
Nutrients ● Dissolved Oxygen ● Organic Matter Inputs ● Groundwater Quality ● Sediment Quality ● Hardness ● Alkalinity ● Turbidity ● Metals ● pH
Physical Integrity
Sunlight ● Flow ● Habitat ● Gradient ● Temperature ● Soils ● Precipitation/Runoff ● Channel Morphology ● Local Geology ● Groundwater Input ● Instream Cover ● Bank Stability
Biological Integrity
Function and structure of biological communities


Chemical Contamination
Toxics ● Low pH ● High Turbidity ● Excess Sediment ● Excess Nutrients/Organics ● Depleted Alkalinity
Physical Degradation
Soil Erosion ● Damaged Habitat ● High Temperature ● Too Much Sunlight ● Too Little/Too Much Flow ● Stream Bank Erosion ● Loss of Groundwater ● Hydromodification
Altered Biological Condition

Biomonitoring

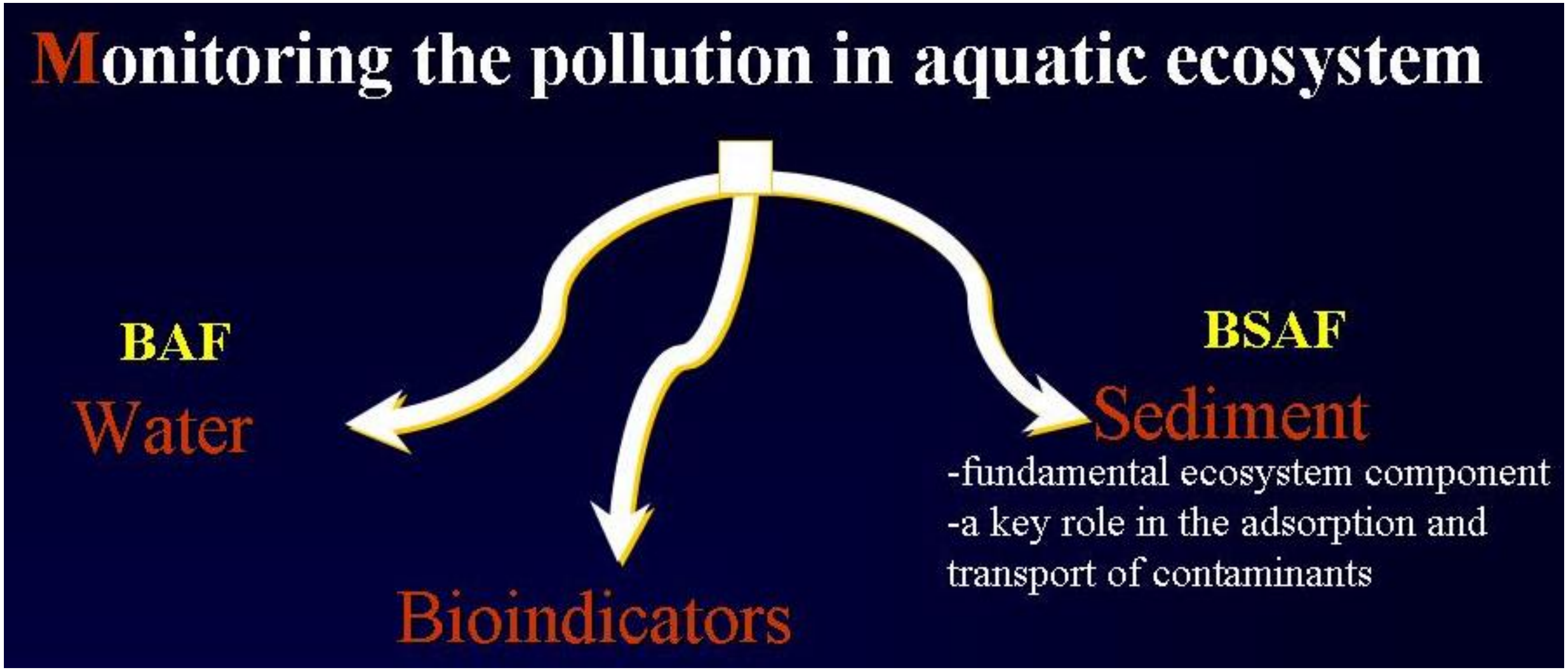
- Biological community respond and integrate wide variety of the environmental factors, whether natural or anthropongenic in origin.

- Use of living organisms as indicators of the quality of surrounding environment.

Why Biological Assessment?

- The use of biomonitoring is growing because it can detect cumulative physical, chemical, and biological impacts of degrading activities.

- Chemical measurements are like taking snapshots of the ecosystem, whereas biological measurements are like making a videotape.



- **Aquatic macroinvertebrates are commonly used in biomonitoring because they are important in moving energy through food webs, wide spread, provide a spectrum of responses to disturbances, and can act as continuous monitors of water quality.**

Types of Biomonitoring Studies

- **Organism level**
  - Biochemical
  - Physiological
  - Morphological
  - Behavioral
  - Life History
  - Bioaccumulation
- **Community Level**
  - Taxa richness
  - Diversity Indices
  - Similarity Indices
  - Biotic Indices
- **Ecosystem Level**
  - Structure of food webs
  - Productivity
  - Decomposition
  - Chemical cycling

- **Biomonitoring methods** provide a range of techniques to assess the impacts of aquatic pollution.

Biological Assessment

Three-step process:

1. Sample aquatic organisms.
2. Summarize data using biological indices.
3. Compare to reference streams.

What is a Biotic Index?

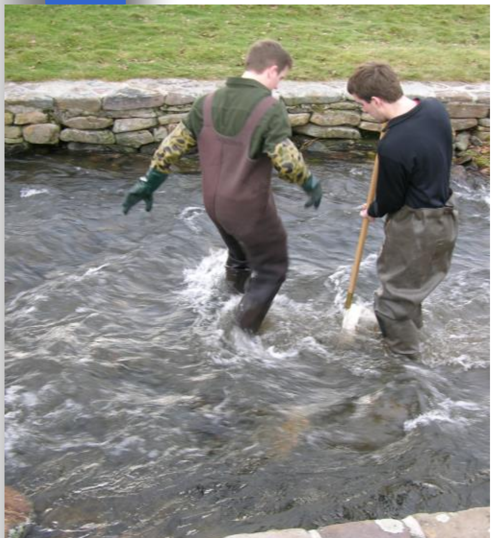
- A Biotic Index is intended to be a measure (scale) of relative ecosystem health based on the organisms present. Essentially it is a way of getting one number to reflect ecosystem quality which you can compare against a given scale.

- It may involve:
  - Taxa presence/absence
  - Taxa abundance
  - Specifically the presence/Absence of pollution intolerant taxa

How can you Calculate a Biotic Index?

1. Collect X-organism
2. Separate your organisms taxonomically
3. Record the information required for your index. This may involve counting individuals within each sample of each specific taxonomic grouping.
4. Plug it into the equations of the biotic index you intend to use

1. Collecting BUGS!



2. Pick your samples (and preserve samples in 90% ethanol)

3. Separate Taxonomically

4. Count abundance and Plug appropriate information into your Index Equations

Some Macroinvertebrate Indexes and Uses

- **Beck's Biotic Index**
  - Sort *individuals* taxonomically and by pollution tolerance
    - Class I = Pollution Intolerant
    - Class 2 = Moderately tolerant
    - Class 3 = Pollution tolerant (not considered)
- **Shannon Weiner Diversity Index**
  - Measure of Diversity
  - This allows us to show:

    (observed diversity)/(maximum possible diversity)
- **Hilsenhoff Biotic Index**
  - Assigns each species a tolerance value which is multiplied by the abundance (number or individuals of that class found)
  - Ranges from 1-10 with 1 being extremely clean and 10 being heavily polluted
  - Higher tolerance values will be for more pollution tolerant individuals
    - So what might we expect of a stream with many pollution tolerants and very few pollution intolerants?

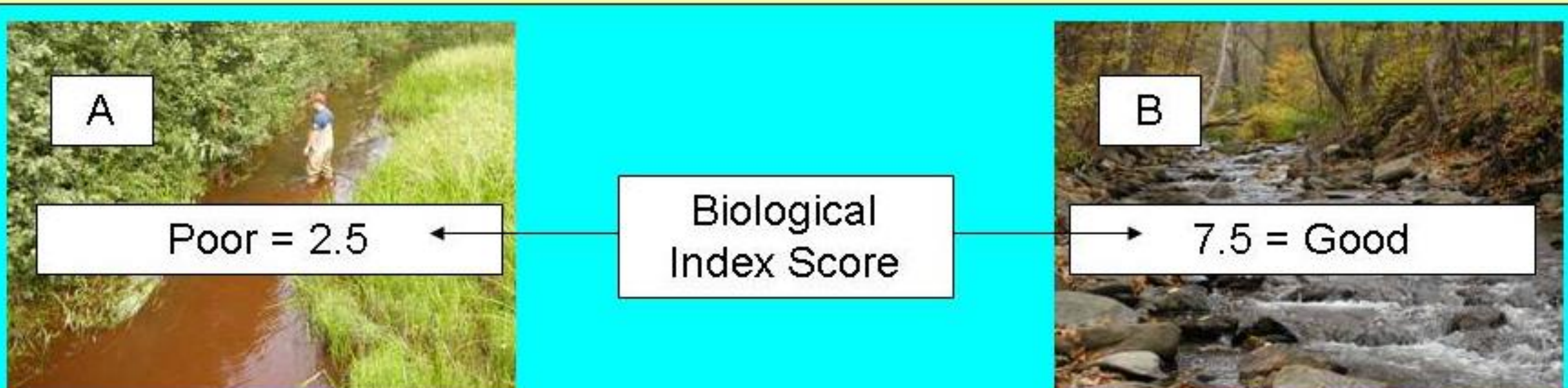
Biological Indices: Interpretive tools for quantifying condition

Steps in developing biological indices:

- Selection of assemblage type(s) that is (are) responsive to changes in environmental condition (i.e. the canary).
- Development of specific “measures” of the biological community that can be used to estimate overall condition (metrics).
- Calibration of metrics to least polluted condition (reference sites).
- Establishment of “threshold” level that represents significant departure from least polluted condition (biocriteria).

Result of biological index development:

- Single number reported that indicates community condition



Macroinvertebrates

"Macro" — Large enough to be seen with the naked eye

"Invertebrate" — Lacking an internal skeleton of cartilage and bones

Invertebrates account for 70% of all known species of living organisms (microbes, plants, and animals)

If we consider just animals, invertebrates account for 96% of known species.

Aquatic insects are about 86 % of known aquatic macroinvertebrates

The Importance of Macroinvertebrates

- Macroinvertebrates are an essential component of aquatic ecosystems
- They serve as food for other organisms (fish, amphibians and waterfowl)
- Are essential to the breakdown and cycling of organic matter and nutrients
- Macroinvertebrate diversity is vital to a properly functioning ecosystem

Classification

Kingdom: Animalia

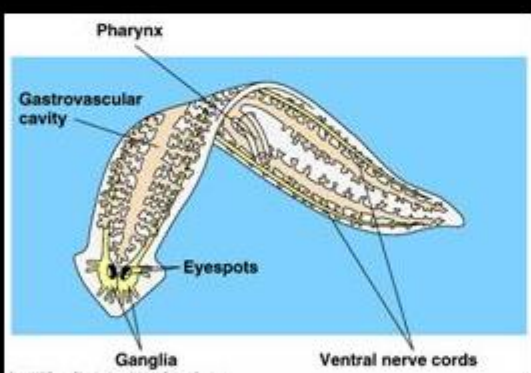
Phylum: **Platyhelminthes**

Arthropoda (Arthropods)

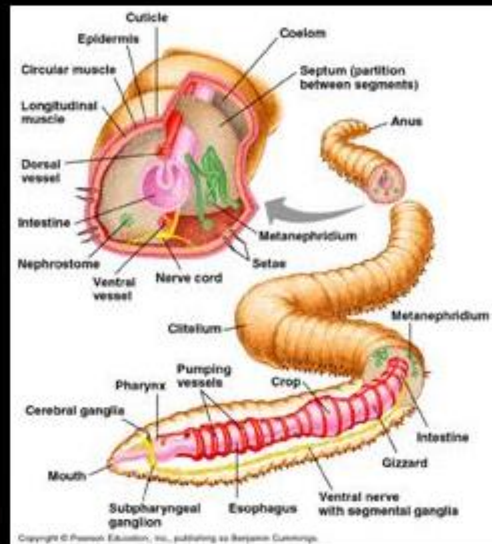
Annelida (Segmented Worms)

Mollusca (Mollusks)

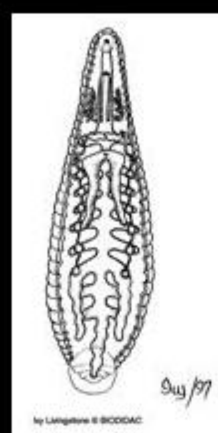
Phylum: Platyhelminthes
Class Turbellaria
Free living flat worm



Phylum Annelida
Class Oligochaeta



Phylum Annelida
Class Hirudinea



Phylum Mollusca
Class Gastropoda,
Family Ancylidae

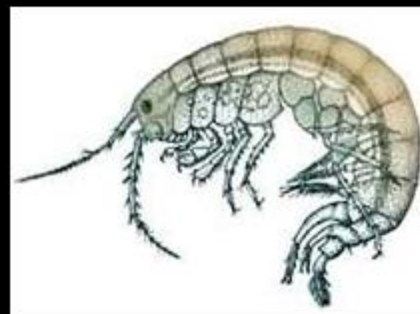
Phylum Mollusca
Class Bivalvia,
Family Unionidae
Freshwater mussels

Phylum Mollusca
Class Gastropoda,
Family Lymnaeidae
Pond snails

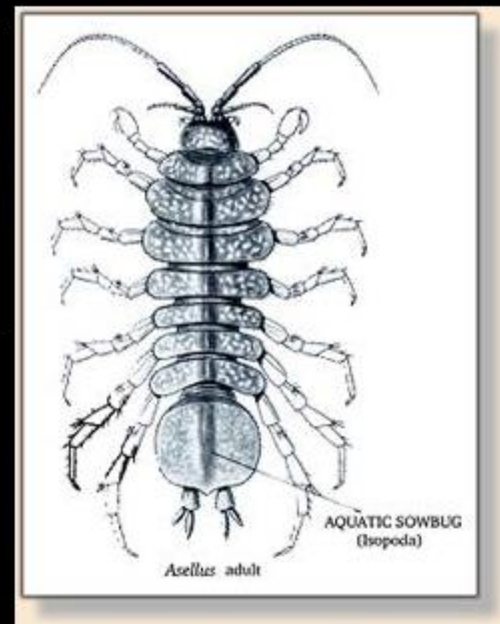
Phylum Mollusca
Class Gastropoda,
Family Physidae
Pouch snails

Phylum Arthropoda
Class Crustacea,
Order Ostracoda
Seed shrimp

Phylum Arthropoda
Class Crustacea,
Order Amphipoda
Scuds, sideswimmers



Phylum Arthropoda
Class Crustacea,
Order Isopoda
Sowbugs



Phylum Arthropoda
Superclass Crustacea,
Order Anostraca
Fairy shrimp

Phylum Arthropoda
Superclass Crustacea,
Order Decapoda
Crayfishes and shrimps

Class Insecta
Order Ephemeroptera

Class Insecta
Order Plecoptera

Class Insecta
Order Odonata

Class Insecta
Order Hemiptera

Class Insecta
Order Megaloptera

Class Insecta
Order Trichoptera

Class Insecta
Order Coleoptera

Class Insecta
Order Diptera

Macroinvertebrate Biology

Habitat ________

Movement ________

Feeding ________

Breathing ________

Life History ________

Stress Tolerance ________

Habitat

The place where an organism lives

Running waters – lotic – seeps, springs, brooks, branches, creeks, streams, rivers

Standing waters – lentic – bogs, marshes, swamps, ponds, lakes

erosional (riffles, wave action) or depositional areas (point bars, pools)

Mineral
bedrock, boulders, cobbles, pebble, gravel, sand, silt, clay

Organic
live plants, detritus

Movement

Locomotion, habits, or mode of existence

Clingers – **maintain a relatively fixed position on firm substrates in current .**

Climbers – dwell on live aquatic plants or plant debris.

Crawlers – have elongate bodies with thin legs, slowly move using legs.

Sprawlers – live on the bottom consisting of fine sediments.

Burrowers – dig down and reside in the soft, fine sediment.

Swimmers – adapted for moving through water.

Skaters – adapted to remain on the surface of water.

Feeding

Macroinvertebrates are described by **how** they eat, rather than **what** they eat

Functional Feeding Groups – **categories of macroinvertebrates based on body structures and behavioral mechanisms that they use to acquire their food**

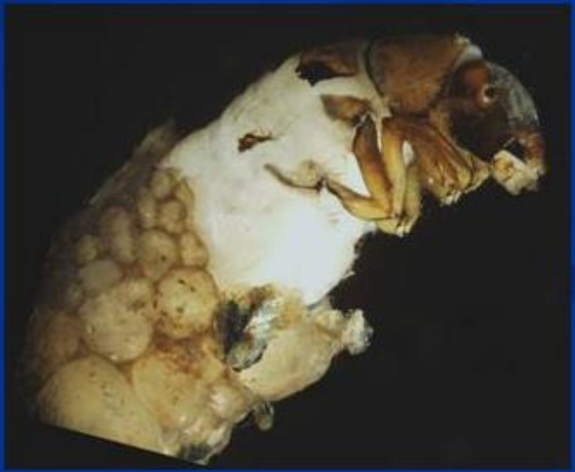
Shredders

Chew on intact or large pieces of plant material

- have basic mouthparts, without any special modifications
- basic mouthparts include two jaw like structures (mandibles) for cutting and grinding and often an upper lip (labrum) and a lower lip (labium) to help keep food in their mouths
- Material is usually >1 mm, referred to as Coarse Particulate Organic Matter (CPOM)

Shredder-herbivores feed on living aquatic plants that grow submerged in the water (northern casemaker caddisflies)

Shredder-detritivores feed on detritus, or dead plant material in a state of decay (giant stoneflies)



Collectors

Acquire and ingest very small particles (<1 mm) of detritus, often referred to as fine particulate organic matter (FPOM)

Collector-gatherers – eat fine detritus that has fallen out of suspension that is lying on the bottom or mixed with bottom sediments

- position themselves on the bottom and eat the detritus from the top of the sediment (non-biting midges)
- burrow through the bottom and unselectively swallow the sediment and fine detritus as they go (aquatic earthworms)
- finger-like projections from some of the mouthparts (palps) help them gather the fine particles of food

Collector-filterers- use special straining mechanisms to feed on fine detritus that is suspended in the water

- spin nets from silk (netspinner caddisflies)
- have hairs on their heads (black flies)
- appendages create water current for their feeding (mussels)

Piercers

mouthparts, or sometimes their entire head, protrude as modifications to puncture food and bring out the fluids contained inside

mouthparts are modified into one or two hard, sharp, hollow tubes that they use to stab into their prey (water scorpions)

Piercer-herbivores – penetrate the tissues of vascular or aquatic plants or individual cells of filamentous algae and suck the liquid contents (crawling water beetles, microcaddisflies)

Piercer-predators – subdue and kill other animals by removing their body fluids

Scrapers/Grazers

- Adapted to remove and consume the thin layer of algae and bacteria that grows tightly attached to solid substrates in shallow waters
- Jaws of scrapers have sharp, angular edges (function function like using a putty knife or paint scraper)
- After algae has been removed, the material is swept into the mouth by finger like projections from other mouthparts

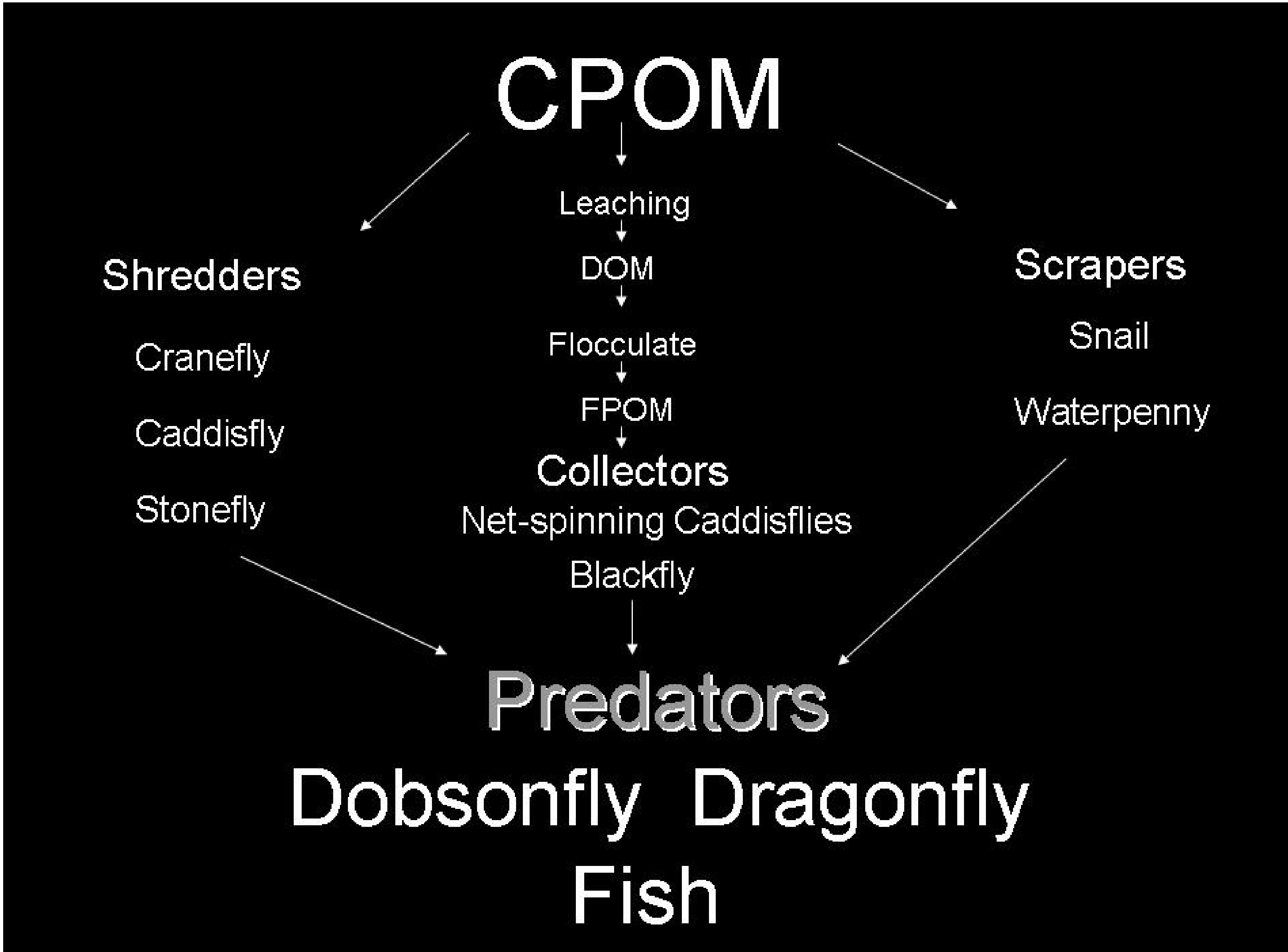
(flathead mayflies, water pennies, snails)

Engulfer-Predators

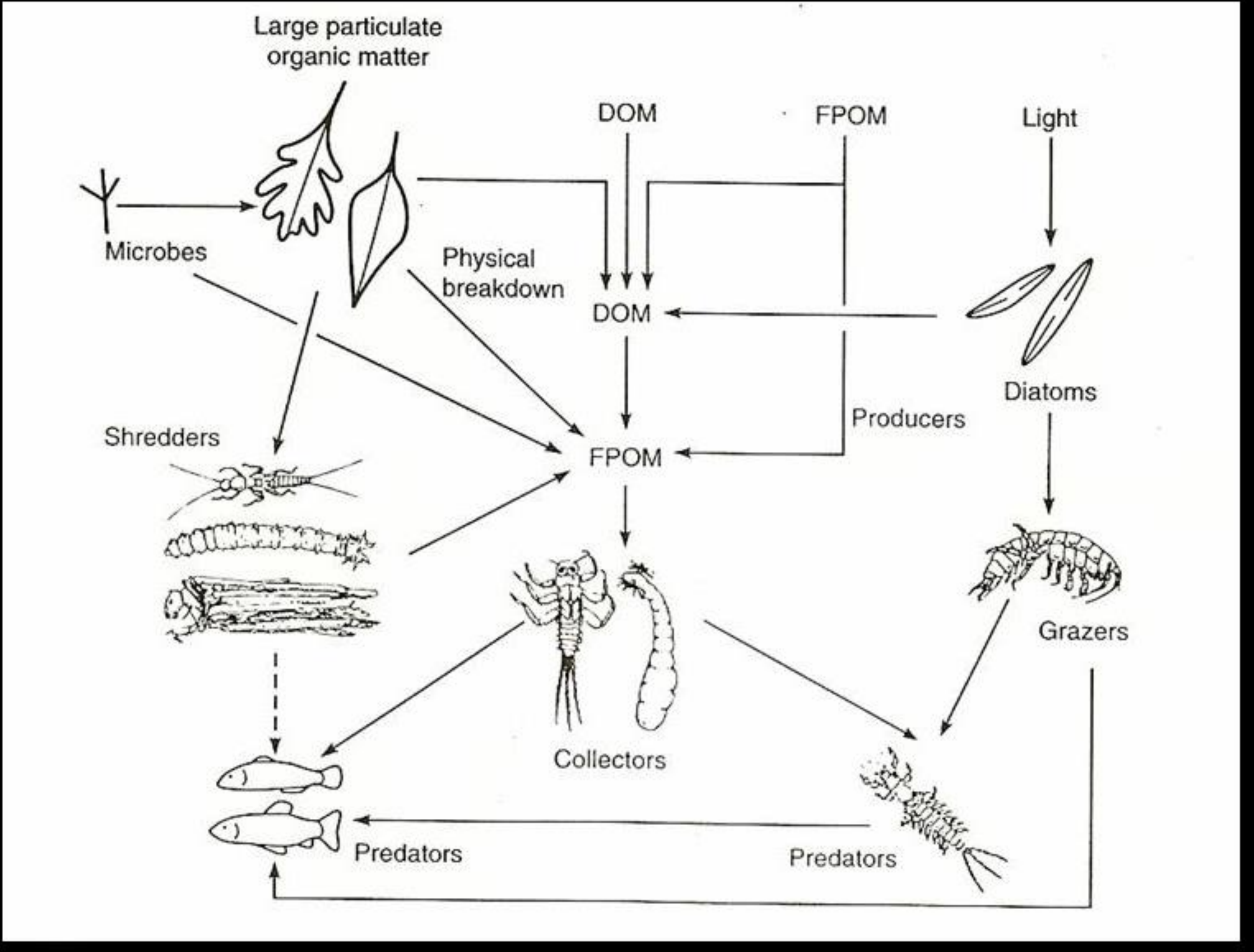
- Feed upon living animals, either by swallowing the entire body of small prey or by tearing large prey into pieces that are small enough to consume

- Typically have large jaws with pointed ends and sharp, tooth like projections for attacking and devouring their prey

e.g. (common stoneflies and hellgrammites)


CPOM
Leaching
DOM
Flocculate
FPOM
Collectors
Net-spinning Caddisflies
Blackfly
Shredders
Cranefly
Caddisfly
Stonefly
Scrapers
Snail
Waterpenny
Predators
Dobsonfly Dragonfly
Fish

Qualitative food web



Autochthonous vs. Allochthonous Inputs

Autochthonous – the relative amount of biomass produced within the system (in stream) algae, periphyton, macrophytes

Allochthonous – the relative amount of biomass produced outside the system (riparian and upland) tree and shrub leaves and needles

Light is a primary determinant of whether the food base for a given community is live green plants growing within the aquatic environment or decaying plant material that originated in the terrestrial environment

Breathing

Closed Breathing System

depend upon oxygen dissolved in the water for their breathing

Oxygen enters the organisms by simple diffusion either through their general body surface or through gills that are specialized for this purpose, or both

Some have behavioral mechanisms, such as wriggling the body, to increase the rate of oxygen diffusion

Open Breathing System

obtain oxygen directly from the atmosphere

All some attach a quantity of air to their body, called an air store, and take it underwater to breathe from (either in a bubble or in a thin layer)

Others breathe by pushing either spiracles or some type of extension on the end of their body to the surface to reach the atmosphere (breathing tubes or siphons)

Life History

Reproduction, growth and development of an organism

Hermaphroditic organisms – contain both male and female reproductive organs (flatworms, aquatic earthworms, leeches, snails and mussels)

Oviparous – females lay their eggs outside of their body

Ovoviviparous – females retain their eggs and allow them to hatch within their body and release free-living offspring

Growth is relatively simple in flatworms, aquatic earthworms and leeches because they are not restricted by any type of external protective structures

Exoskeletons of arthropods does not grow once it has been produced, so growth of the organism is restricted. As a result, arthropods must shed their skin (molt) in order to increase in size (3-45 times).

Mollusks are enclosed in non-living protective covers produced by the organism, called shells; shells are made of protein and calcium carbonate; made larger by adding material, like a tree growth ring

Stress Tolerance

Natural

volcanoes, forest fires, floods, landslides

Anthropogenic

pollution, removal of water by irrigation, dams, deforestation, removal of riparian vegetation

Freshwater invertebrates vary in their ability to cope with environmental stress

Biomonitoring takes advantage of this situation by identifying whether an aquatic environment is inhabited predominantly by stress tolerant or stress intolerant organisms

Bioassesment of macroinvertebrate communities in relation to water quality in Manzala Lake, Egypt.

" التقييم البيولوجى لمجتمع اللافقاريات الكبيرة وعلاقته بجودة
المياة فى بحيرة المنزلة - جمهورية مصر العربية"

Objectives

- The overall objective of this study is to identify the macroinvertebrates community structure in relation to the physico-chemical conditions in lotic and lentic habitats and using the data in the bioassesment of water quality in Manzala Lake.

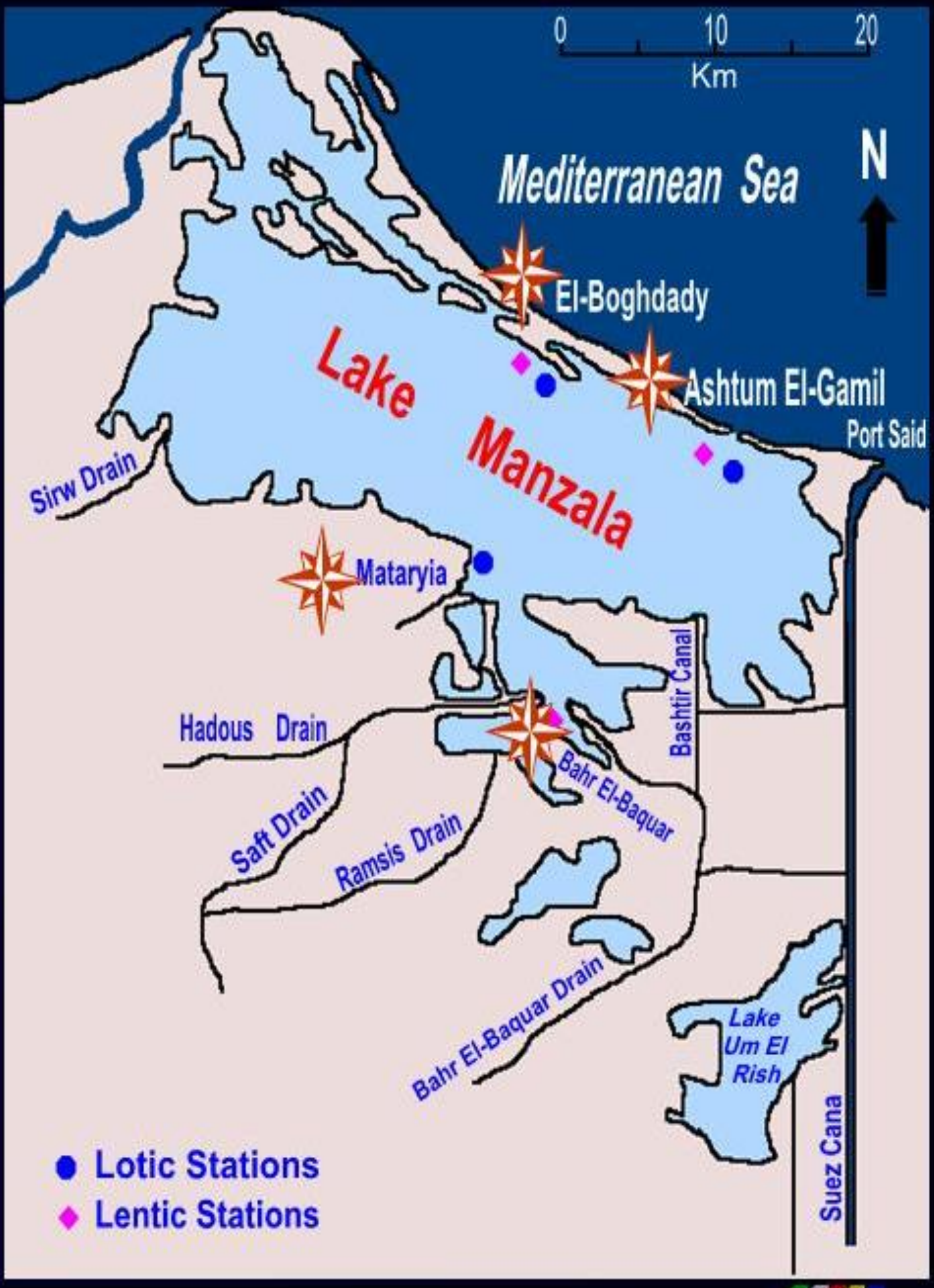
Study area

Lake Manzala

Types of discharge

- Industrial
- Domestic
- Agriculture

Eutrophic, complex aquatic system, receives saline water from Mid. Sea and Suez canal and fresh water from Nile and drains.



Manzala Lake was conducted at four sites (Ashtum El-Gamil, El-Boghdady, Bahr El-Baquar and El-Matariya) which dividing into lotic and lentic habitats from July 2002 to December 2003.

Lotic

Lentic

Ashtum El-Gamil

Lotic

Lentic

El-Boghdady

Lotic

Lentic

Bahr El-Baquar

Lotic

El-Matariya

Biotic metrics of macroinvertebrate community

- Seasonal abundance.
- Taxa richness.
- Shannon's diversity index.
- Hilsenhoff biotic index.
- Percent contribution of the dominant taxon.
- Percent isopods, snails & leeches.
- Percent trophic functional feeding groups.
- Ratio of scraper/filtering collector.
- Ratio of scraper/gatherer collector.

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- Percent trophic functional feeding groups.
- Ratio of scraper/filtering collector.
- Ratio of scraper/gatherer collector.

- The community within the study area was primarily of **freshwater origin** as **aquatic insects** and some of **marine origin** as **crustaceans** and **mussels**.

- Community composition and abundance showed a considerable significant difference between **lotic** and **lentic** stations. lentic taxa are **more frequent** than lotic ones.

- The fauna was dominated by aquatic insects, **tolerant** and **very tolerant** species. **Sensitive** and **very sensitive** species are completely absent.

- Highly abundance of most species was during spring and summer .

Ephemeroptera

Plecoptera

Tricoptera

Decapoda

Very Sensitive

Amphipoda

Dragon fly

Damsel flies

Carabidae
Bivalve

Sensitive

Coleoptera

Hemiptera

Isopoda
Sawbugs

Tolerant

Aquatic earthworm

Leech

Aquatic snail

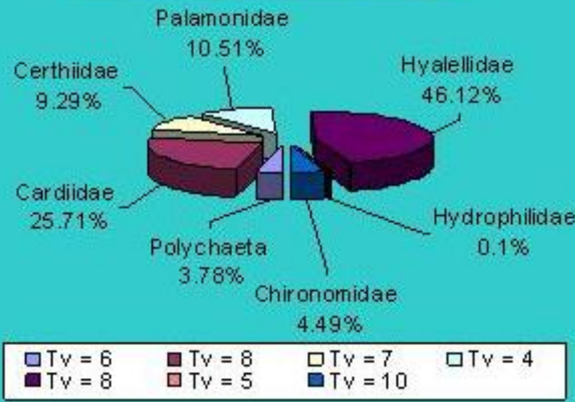
Diptera
Midge larva

Very tolerant

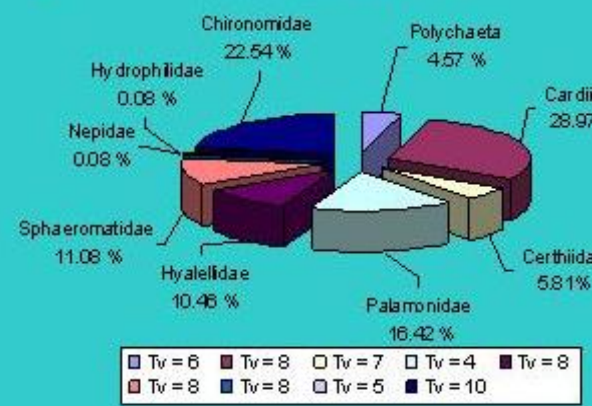
Abundance of macroinvertebrate families at lotic stations

Abundance

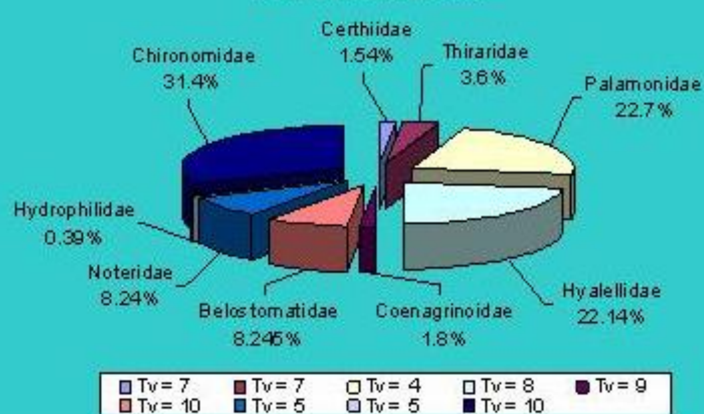
Ashtum El-Gamil lotic



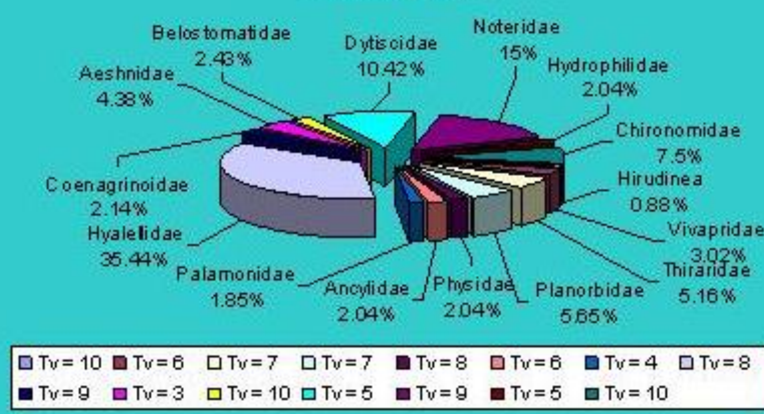
El-Boghdady lotic



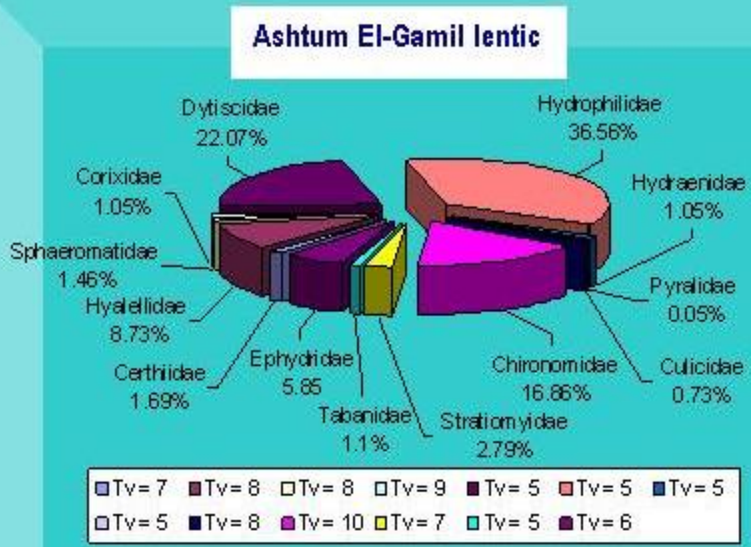
Bahr El-Baquar lotic

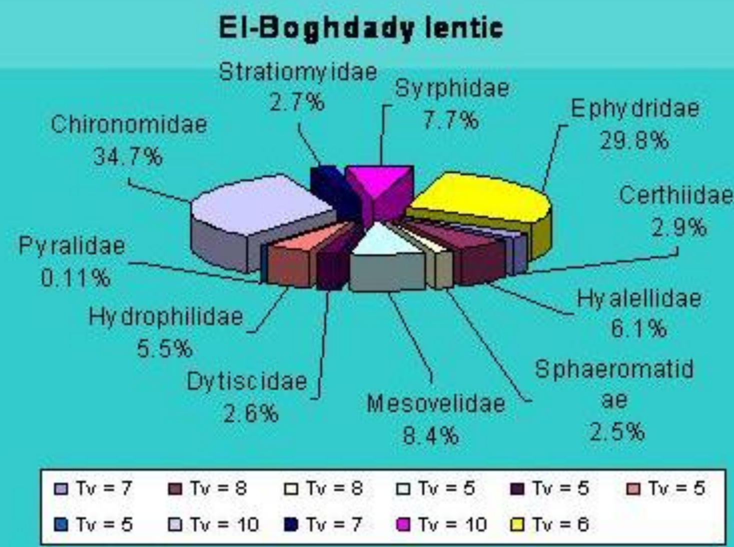


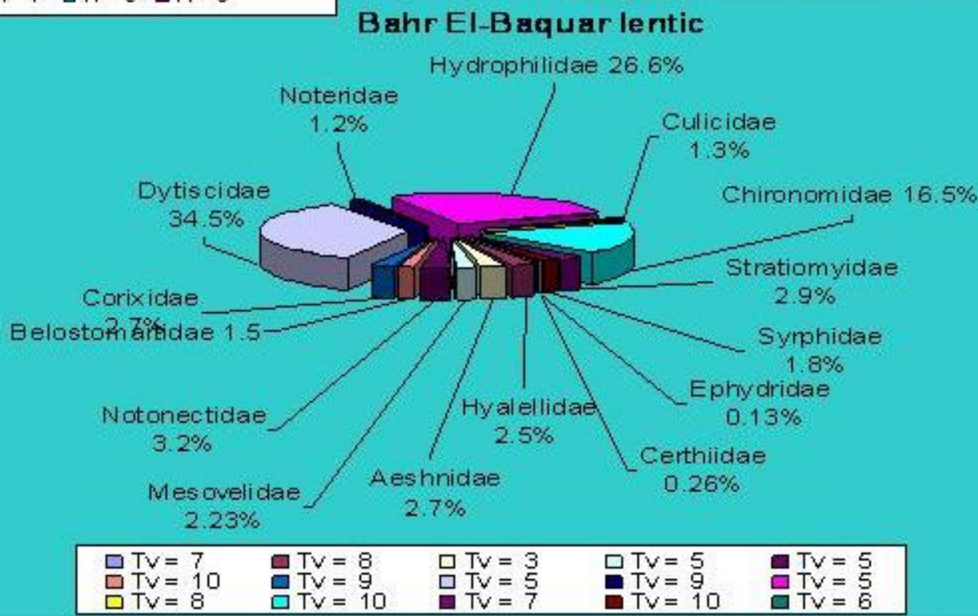
El-Matariya lotic

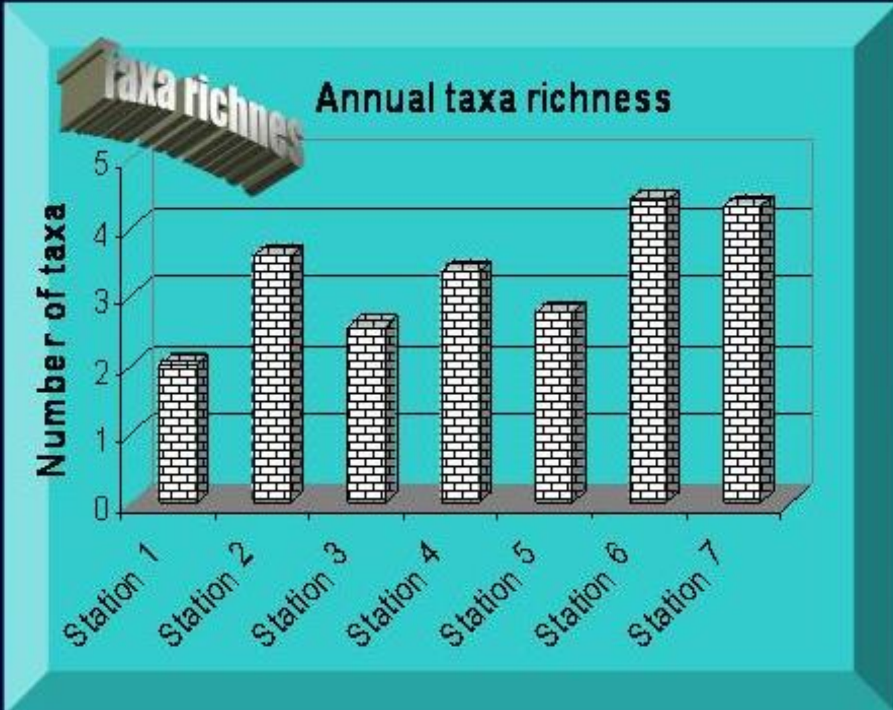


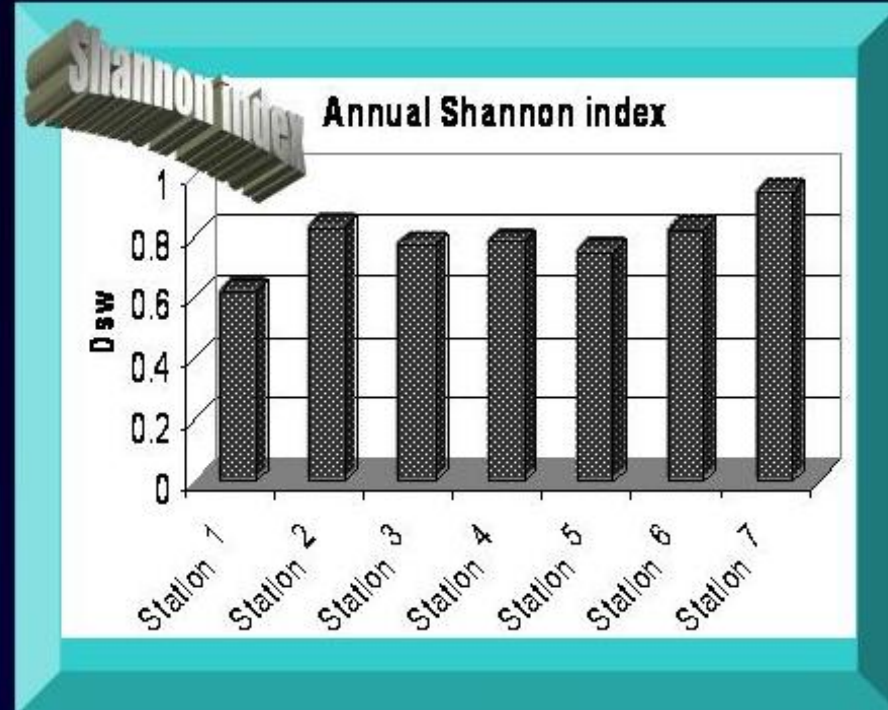
Abundance of macroinvetebrate families at lentic stations

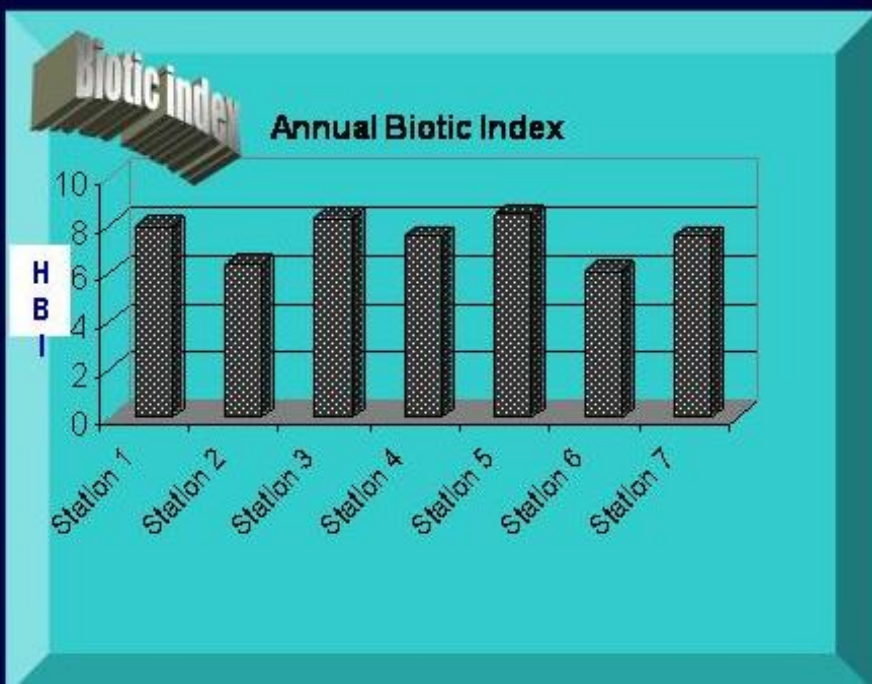






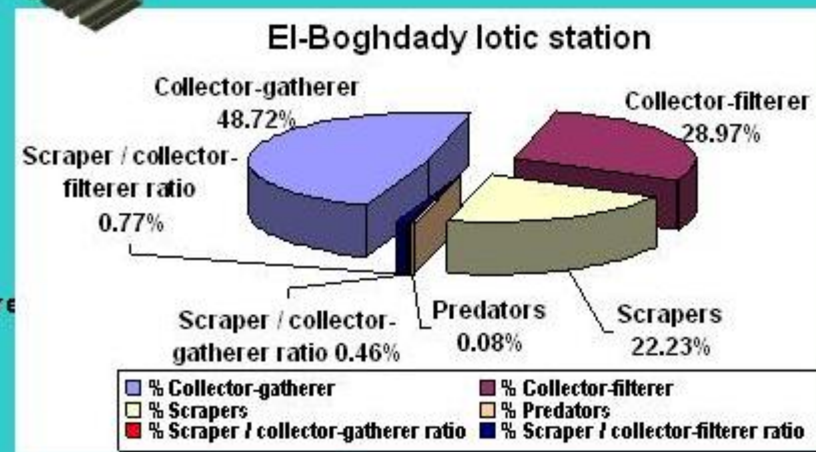

Taxa richnes
Annual taxa richness
Number of taxa
0
1
2
3
4
5
Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7


Shannon index
Annual Shannon index
Dsw
0
0.2
0.4
0.6
0.8
1
Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7

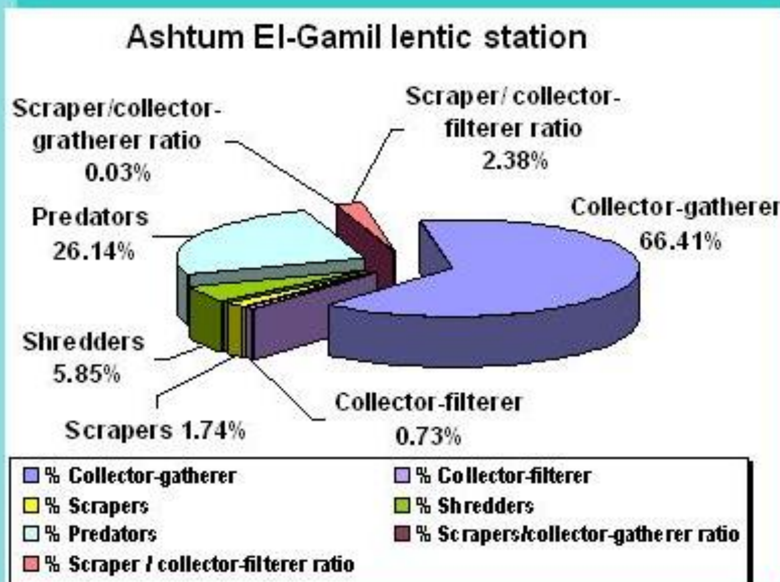

Biotic index
Annual Biotic Index
HBI
0
2
4
6
8
10
Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7

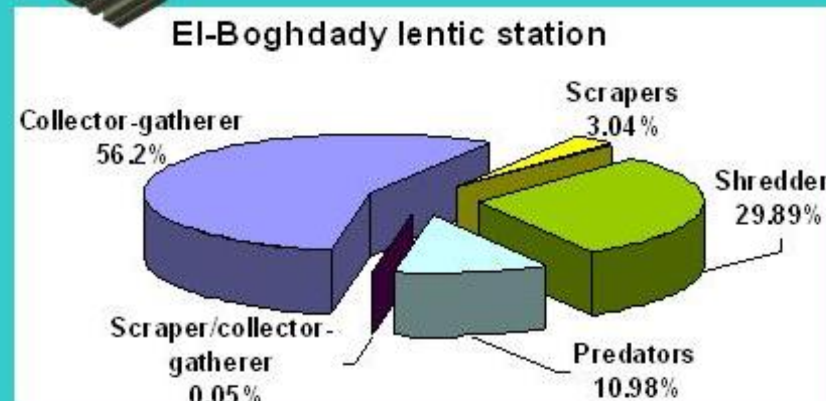

Dominance
Annual Dominance
Number of taxa
0
10
20
30
40
50
Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7

Trophic functional feeding groups at Lotic stations.



Trophic functional feeding groups at lentic stations.



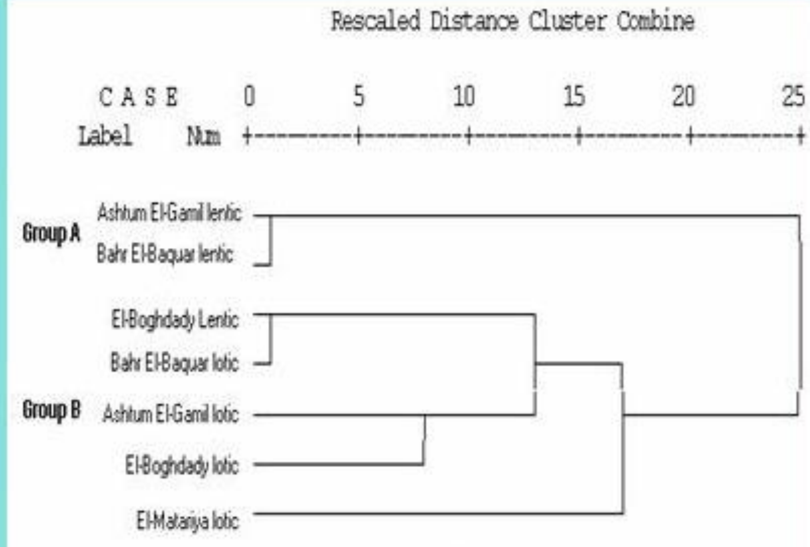


Cluster Analysis

- The cluster analysis technique was used to group stations into clusters based on the similarity of the macroinvertebrate communities, biotic metrics and physico-chemical parameters.

- Stations which are closely linked will be next to each other and connected by short lines. Stations which are dissimilar are separated by greater line lengths.

- The dendogram separated into **two major groups**, the first one contains Ashtum El-Gamil lentic and Bahr El-Baquar lentic stations that are closely linked together. The second group contains other three groups, El-Matariya lotic station which present in separated clade, El-Boghdady lentic and Bahr El-Baquar lotic that are similar and Ashtum El-Gamil lotic and El-Boghdady lotic stations that are similar too



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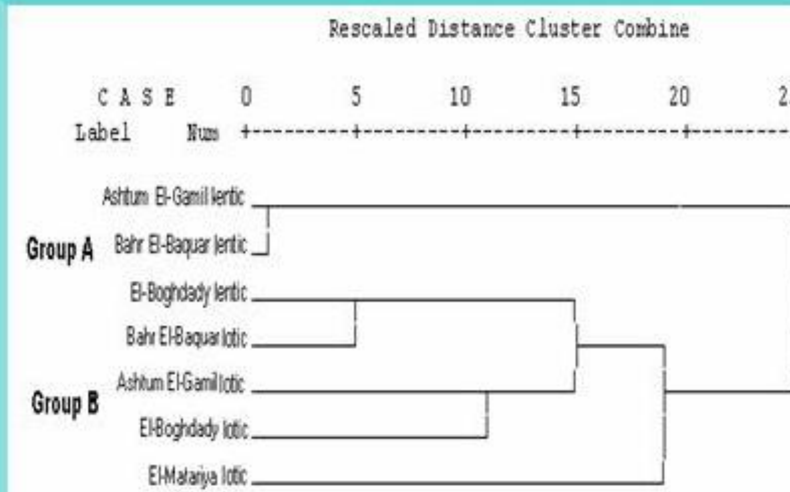


(17)

Assessment

The macroinvertebrate assemblage, biotic metrics and physico-chemical parameters at all stations of Manzala Lake are indicative of degraded conditions. The community was dominated by pollution-tolerant species. An assessment of water quality indicates that it ranges from

fair, fairly poor, poor, very poor.

Stations	HBI	Water quality	Degree of organic pollution
Ashtum El-Gamil lotic	5.44	Fair	Some organic pollution
Ashtum El-Gamil lentic	6.36	Fairly poor	Fairly significant organic pollution
El-Boghdady lotic	5.32	Fair	Some organic pollution
El-Boghdady lentic	7.54	Very poor	Very significant organic pollution
Bahr El-Baquar lotic	7.92	Very poor	Very significant organic pollution
Bahr El-Baquar lentic	6.16	Fairly poor	Fairly significant organic pollution
El-Matariya lotic	7.54	Very poor	Very significant organic pollution

Morphological deformities and cytogenetic alterations in *Chironomus plumosus* L. (Diptera: Chironomidae) larvae as biological indicators of toxic stress in Temsah Lake, Egypt.

"استخدام التشوهات الظاهريه والتغيرات الوراثيه الخلويه في يرقات كايرونومس بلومسس (ثنائيه الاجنحه - كايرونوميدي) كدلالات بيولوجيه علي السميه في بحيره التمساح - جمهورية مصر العربية"

- This is the first study on morphological abnormalities and cytogenetic alterations of the Egyptian chironomid populations to determine the influence of environmental contamination.

Egg mass

live Larva

Preserved Larva

Adult

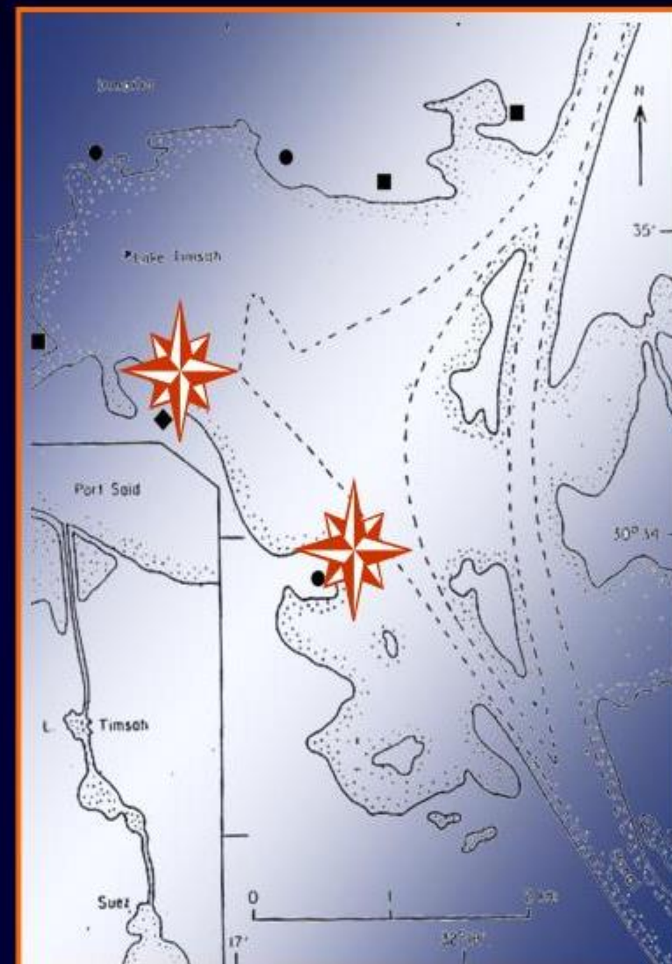
Pupa

Study area

Lake Timsah

Types of discharge

- • Industrial
- ▪ Domestic
- ♦ Agriculture



Objectives

- Document the types of deformities in *C. plumosus* L. larvae from two differentially stressed sites in Temsah Lake.
- Explore the range of severity in these deformities and compare their frequencies in the two sites.
- Investigate if concentrations of heavy metals in midge larvae could be related to metal levels in water and sediment.
- Establish whether there was an association between mouthpart deformities and nucleolus activity in the polytenic chromosomes.

Conclusion

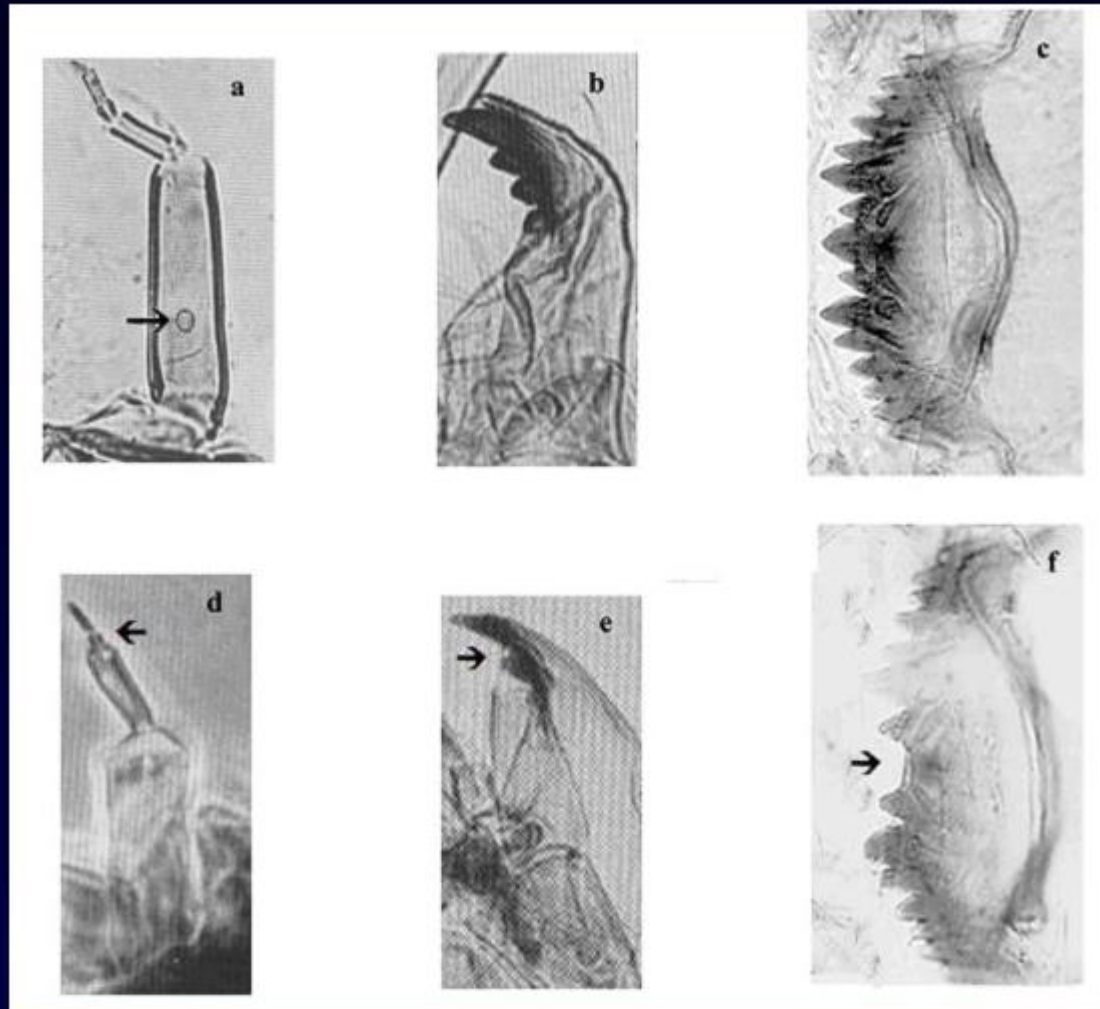
- The **frequency** and **severity** of **deformities** were higher at **site II** in antennae, mouthparts structures and chromosomes.

- Larvae presenting morphological deformities had a significantly higher incidence of active nucleoli in their polytenic chromosomes than other larvae.

- The concentration of metals was higher in the sediment compared to water. The level of Fe was higher in the larva tissues than in water and sediment.

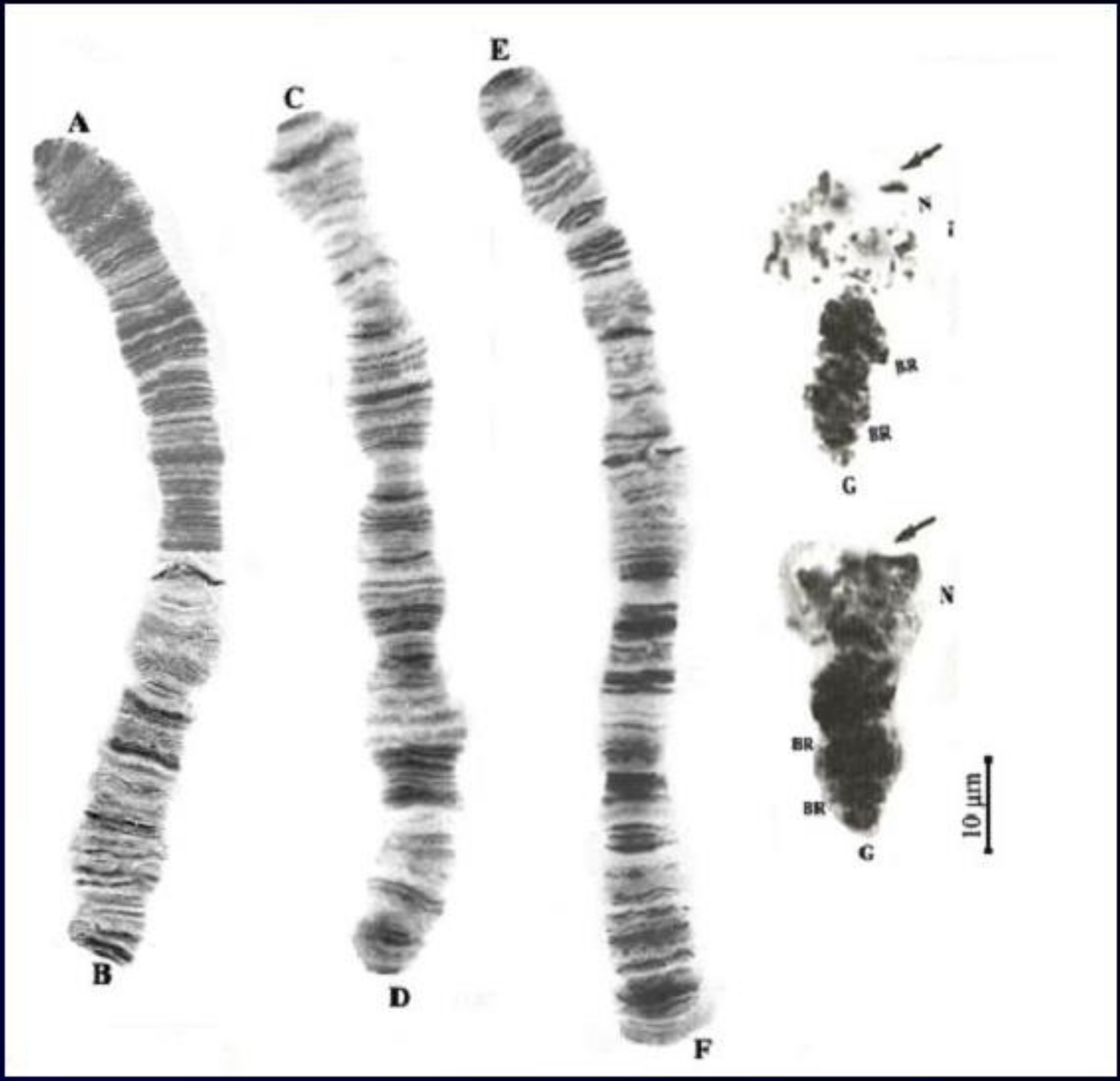
- The bioaccumulation factor (BAF) and biota sediment accumulation factor (BSAF) of Fe, Zn and Pb in tissues of the midges collected from site II, which receives industrial discharges were higher than in midges collected from site I, which receives domestic discharges.

- This study confirmed the hypothesis that deformities in *Chironomus* M. larvae are environmentally induced and caused by contaminants in the sediment.

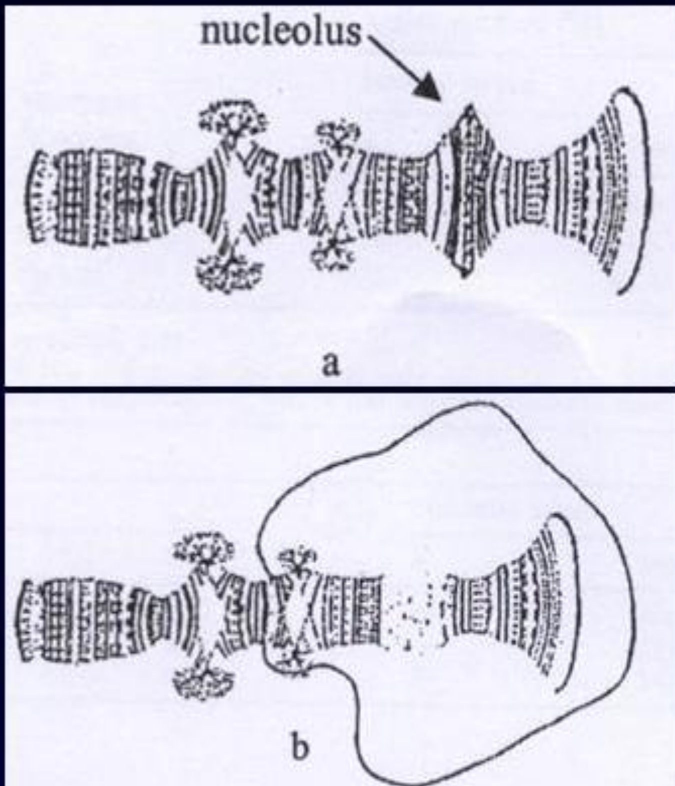


Chironomus plumosus. Antenna a, normal; d, fusion of segment 3 & 4 deformed. Mandible b, normal; e, with one subapical tooth. Mentum c, normal; f, median area with gap.

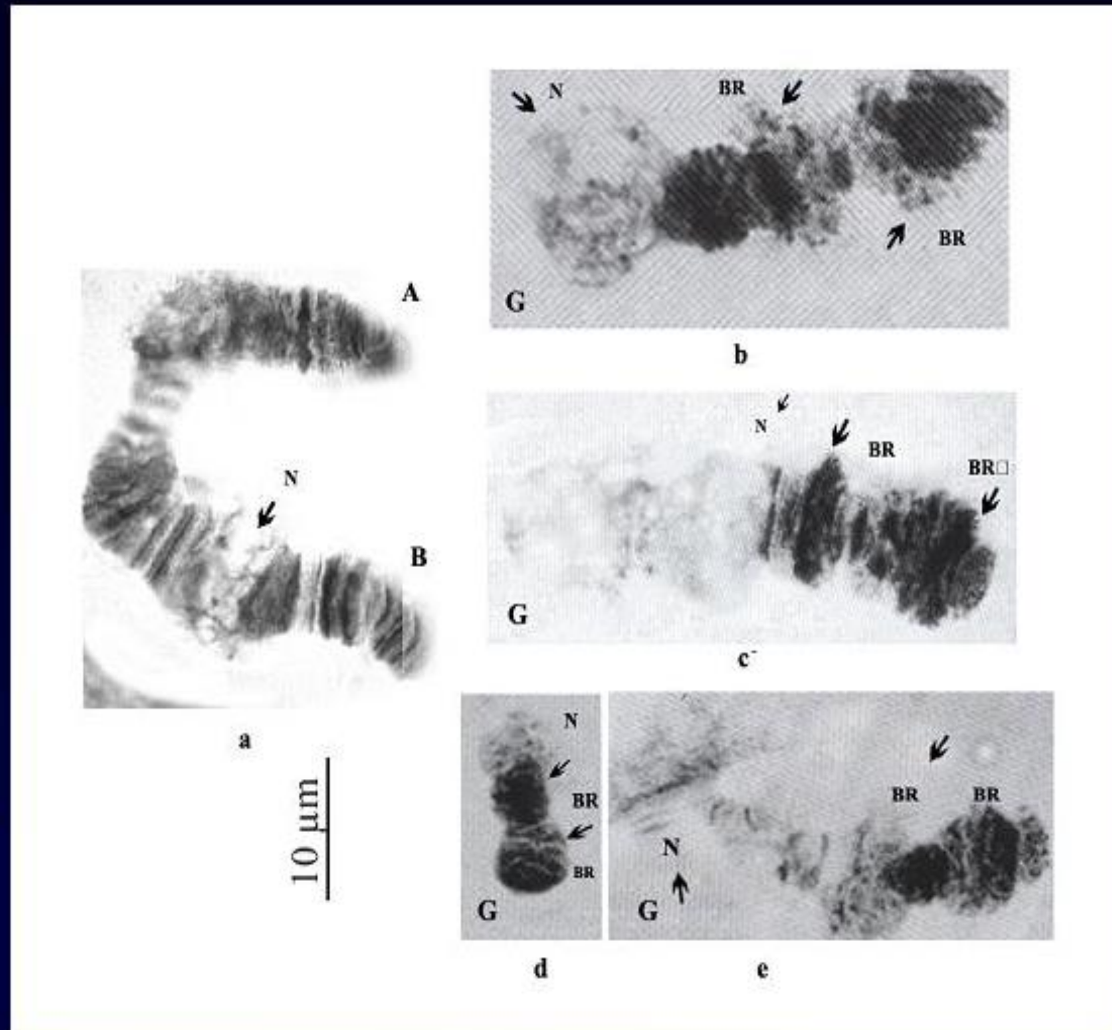
- Most species have a diploid no. of chromosomes   2n = 8.
- The following designation of the chromosomes was accepted: AB -I, CD- II, EF- III, G – IV.
- The nucleolus organizer is in the G – IV chromosome.
- Nucleoli are the site of **rRNA synthesis**
- Polytene chromosomes of the deformed larva were characterized by very active nucleoli especially in G – IV chromosome ----- increased rRNA synthesis ----- higher protein synth.
- The synth. of proteins may increase deformed larva tolerance to toxicants



Chromosome map of *Chironomus plumosus*; Normal chromosomes: N, nucleolus; BR, Balbiani ring; ⬇ centromere, after Michailova and Krastanov (2000).



Schematic representative of nonactive (a) and active (b) nucleoli on the chromosome G



Deformed chromosomes of *Chironomus plumosus*;

All chromosomes with **active nucleoli**.


Thank you