DOCUMENT RESUME

ED 099 224	88	SE 018 304

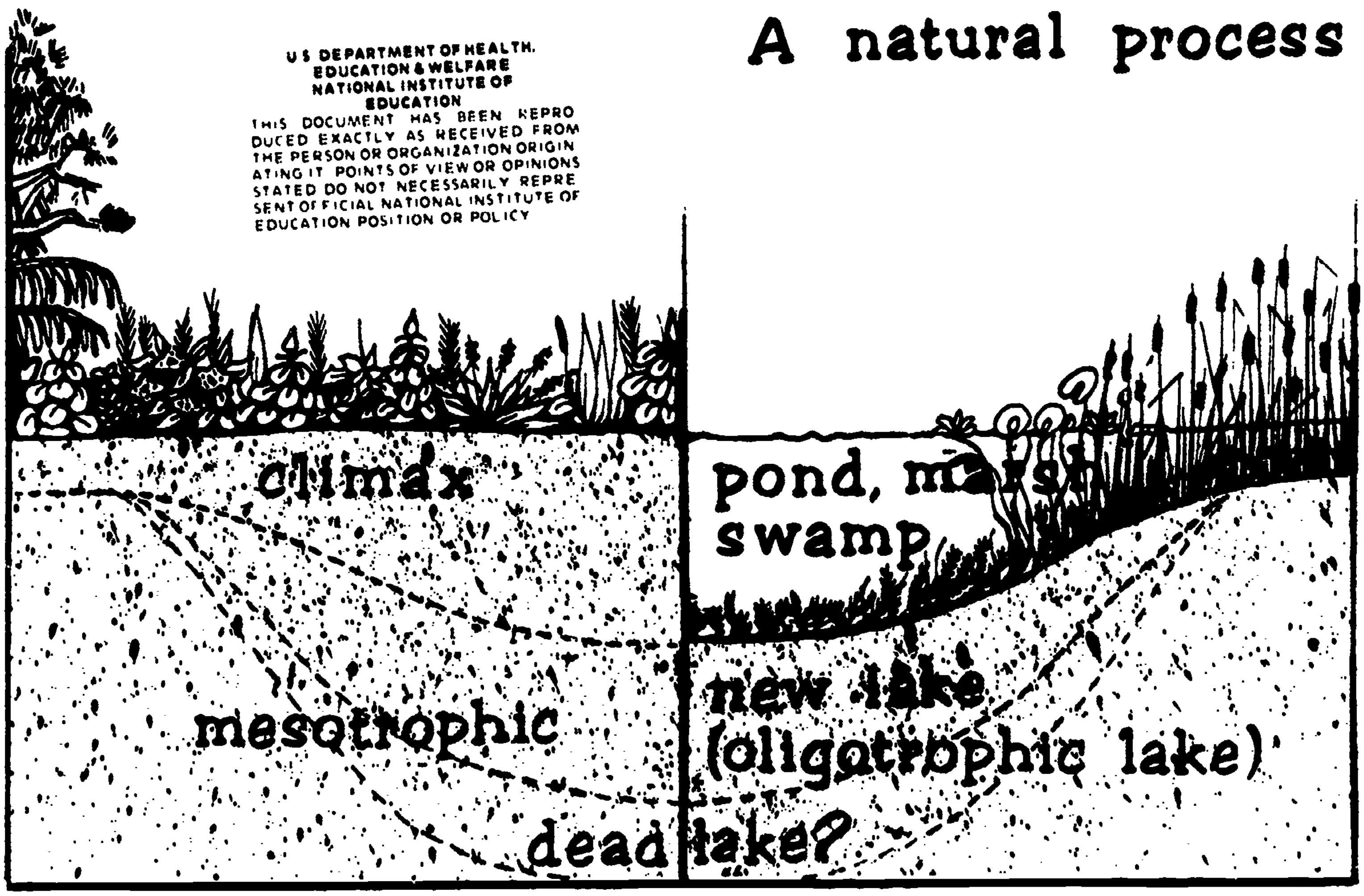
AUTHOR	Monsour, William
TITLE	Eutrophication, A Natural Process.
INSTITUTION	Broward County School Board, Fort Lauderdale, Fla.
SPONS AGENCY	Bureau of Elementary and Secondary Education (DHEW/OE), Washington, D.C.
PUB DATE	73
NOTE	21p.
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	Conservation Education; Environment; *Environmental Education; *Instructional Materials; Interdisciplinary Approach; Language Arts; Natural Resources; *Science Education; Secondary Education; Social Studies; *Teaching Guides; Unit Plan; *Water Resources
IDENTIFIERS	Elementary Secondary Education Act Title III; ESEA Title III; Eutrophication

ABSTRACT

This environmental education learning unit deals with the topic of eutrophication. The unit is designed to allow secondary teachers of science, language arts, and social studies to use it as supplementary material in their classroom. Teacher information, unit objectives, the unit text, and appendices are included. The teacher information section provides the teacher with directions and suggestions for use of the unit. The objective around which the unit is designed is to provide the student with information, knowledge, and data on eutrophication. The unit reflects the objective, consisting of a text which deals with the formation of lakes, the effects of nutrients, time, and sedimentation on the process of eutrophication, and the causes and effects of cultural eutrophication. A diagram of factors affecting the eutrophication of lakes, a list of essential algae nutrients, a multiple choice pre-post test and key, and a bibliography are included in the appendices. (TK)

EUTROPHICATION

A natural process



INTERDISCIPLINARY
ENVIRONMENTAL EDUCATION

An ESEA Title III Project
based at Nova High School
BROWARD COUNTY, FLORIDA

The work presented or reported herein was performed pursuant to a grant from the U. S. Office of Education, Department of Health, Education and Welfare. However, the opinions expressed herein do not necessarily reflect the position or policy of the U. S. Office of Education and no official endorsement by the U. S. Office of Education should be inferred.

INTERDISCIPLINARY ENVIRONMENTAL EDUCATION PROJECT
An ESEA Title III Project
The School Board of Broward County, Florida

IEE Offices
Nova High School
3600 S. W. College Avenue
Fort Lauderdale, Florida 33314

IEE STAFF:

William Thrasher, Coordinator
William Monsour, 9-12 Specialist
Nancy Hougendobler, 6-8 Specialist
Marilyn Laskey, K-5 Specialist
Wayne Bernard, Printer-Technician
Elsie Prince, Secretary
Maureen Moyer, Secretary
Ellen Moss, Secretary

WRITER:

William Monsour

DIRECTOR IEE PROJECT:

John E. Arena

DIRECTOR NOVA SCHOOLS:

Warren G. Smith

I nave reviewed this package for content in terms of curriculum and appropriateness.

John Arena
IEE Director

Date: 2/27/73

TO THE TEACHER

This is a learning unit designed to allow teachers of science, language arts, and social studies to utilize supplemental materials in their classrooms. It is in no way intended to disrupt the continuity of the teachers' planned objectives but is merely a vehicle that may complement a topic under discussion during the class year.

The social studies teacher may find it appropriate to present this unit when teaching the implications of high population densities in communities with limited water supplies; agricultural storm runoffs and their influence upon standing bodies of water (lakes, ponds); economic considerations of eutrophied standing bodies of waters; political issues dealing with destruction of the environment (cross-country Barge Canal controversy); and many others.

The science teacher will find the unit applicable to many ecological concepts. Included are topics on the formation of lake basins, aging of lakes, algal blooms, specie domination, specie diversity, succession, photosynthesis, respiration, and many other areas.

Debate has long been used by language arts teachers as an important learning tool. There are issues included in the unit dealing with cultural eutrophication that many may argue. Should farmers be made to move out of areas because they enhance eutrophication problems or should they remain and continue to add to the destruction of our reservoirs?

The environmental problems we are faced with affect all individuals, not just the science-oriented student. The relationships between disciplines dealing with these problems have been mentioned but many more are possible. Examine the unit carefully. The selected bibliography (Appendix E) will serve to lead you into many areas that lend themselves to subjects you may have found to be limited in the past.

This learning unit is a presentation that may be given in two forty-five minute class periods.

The teacher may begin by giving a pretest (Appendix C) before the Unit and post test after completing the Unit. A test key (Appendix D) has been provided.

OBJECTIVES

To provide students with enough information, knowledge, and data that will enable them to:

1. define eutrophication in terms of
   - (a) overenrichment of a water body
   - (b) a natural process
   - (c) an unnatural process due to the activities of man
   - (d) the aging of a lake
   - (e) ecological succession
   - (f) stratification and overturning
   - (g) the consequences of an abundance of nutrients in a water body
   - (h) dissolved oxygen
   - (i) possible solutions for controlling its rate
2. discuss briefly the phenomena concerned with the origin of lake basins.

CARD 1

The problem of water pollution, the problem of proper water management, and the problem of water shortage have become priority topics of concern for people like ourselves who live here in Southeast Florida. In recent years, millions of dollars have been allocated for meeting and solving these problems. Unfortunately, water problems have many faces. Of these, the problem of eutrophication is receiving more and more attention each day. Through the efforts of the news media, eutrophication, a word once reserved for the scientist, has become a layman's term. With this increased awareness of eutrophication has come the misconception that it is a new phenomenon and has acquired an added meaning. Eutrophication has become synonymous with pollution.

While it is true that some types of pollution accelerate eutrophication, contamination of water with pollutants such as arsenic or DDT do not contribute to the problem. They, of course, may cause other detrimental effects. The words pollution and eutrophication should not, therefore, be used synonymously.

A eutrophic lake is not a dead lake. In fact, a eutrophic lake is more alive than those lakes which are considered to be in good condition. If this is indeed true, then why is eutrophication of lakes looked upon as a state of degeneration? Why is so much attention, time, and money being spent to evaluate the condition of our water bodies and to slow down or reverse the process of eutrophication?

A simple definition of eutrophication is "the process of enrichment with nutrients." Although this is a very neat description, the process itself is one of great complexity (Appendix A).

The process of eutrophication is a natural one. From the moment of its inception, a new lake begins to age and drift closer to becoming a eutrophic lake. Let's examine the natural process of the aging of a lake through the several stages it takes in its life cycle. (FLIP CARD)

CARD 2

FORMATION OF LAKES - It may be appropriate at this time to allow a few minutes to relate how lakes are formed. The phenomenon concerned in the origin of lake and pond basins are varied but may be reduced to a dozen major processes. A few of these may be of interest to you.

TECTONIC BASINS - Tectonic basins are those depressions formed as the result of some movement of the earth's crust. Lake Okeechobee in Southern Florida gives evidence of being a remnant depression in the Pliocene sea floor which retained its form when uplifted to become land. This lake covers approximately 730 square miles and in the wider area is nearly 24-1/2 miles across. Except for Lake Michigan, Lake Okeechobee is the largest freshwater body completely within the United States. During periods of drought, the depth of this lake may be no more than 14-1/2 feet. The only tributary of any import to Lake Okeechobee is the Kissimmee River, which drains some 3000 square miles and empties into the lake on the north. Several lakes (Apopka and Weir) of Central Florida may have been formed in the same manner, part of the evidence in the latter cases being the presence of a killifish (Cyprinodon hubbsi) whose nearest and closest relative is found in salt and mildly saline waters along the present coasts.

BASINS OF VOLCANIC ORIGIN - Various volcanic activities may form lake basins. A most notable example is Crater Lake, Oregon. This lake occupies a caldera, or volcanic basin near the summit of the volcano, produced by explosion. The surface of the lake lies nearly 2000 feet below the rim and the depth of the lake itself is about 2000 feet. No streams enter Crater Lake, the water being derived from rain and snow melt.

GLACIAL ACTION - Glaciation has been and is a conspicuous force in the formation of lake basins in certain regions of the earth.

The Great Lakes are excellent examples of basins formed by glacial action, and their history has been recorded rather accurately. The original basins, quite different from those of today, were formed during the late Pleistocene by the scouring of previously formed stream valleys. These basins were later shaped by the depression of the land under the weight of the continental ice sheets or, as some authorities believe, by continued erosion of easily fractured minerals.

The history of the Great Lakes begins with the recession of the last ice sheet of the glacial period. During one of its several advances and recessions this ice sheet reached as far south as the junction of the Ohio and Missouri Rivers in the Central United States. As the ice retreated, and after many stages, the Great Lakes took their form.

GEOLOGIC FAULTING - Earthquakes have been responsible for the formation of lake basins such as Reelfoot Lake in Tennessee. This was formed by the New Madrid earthquakes of 1811-1813. The basin of Reelfoot is about 20 miles long and approximately 20 feet deep.

CARD 2 (Cont'd.)

Geologic faulting, the mass shifting of great blocks of rock, forms lake basins by tilting the land surface and by the formation of a basin in which water collects. The basin of Lake Tahoe, California, was formed by the accumulation of water in a graben or trough, resulting from the displacement of crustal masses to form steep walls. In these rift valleys are found such famous waters as River Jordan, the Sea of Galilee, and the Dead Sea.

CRUSTAL FORMATIONS - Less spectacular crustal deformations account for Great Salt Lake in Utah. Here mountains have been thrown up to form a basin from which there is no drainage. Inflowing waters carry dissolved minerals, and rapid evaporation concentrates the salts.

The youngest period of a lake has been characterized by low concentrations of nutrients for plants and little biological productivity. Lakes in this phase of their life cycle are often referred to as OLIGOTROPHIC (from the Greek oligo meaning "few" and trophein meaning "to nourish"). Thus oligotrophic means few nutrients. (FLIP CARD)

CARD 3

Enrichment of the lake increases as the lake gets older. As a rule, a lake will capture a portion of the nutrients which comes into it and will gradually increase the total amount of nutrients present. During this aging of the lake it becomes MESOTROPHIC (meso = intermediate). This stage is characterized by sediment buildup on the lake bottom. The most obvious changes that you will notice around the lake takes place as one form of plant follows or succeeds another. This process, called "succession," occurs in nearly all the world's habitats, but nowhere is it more evident than in a pond. (FLIP CARD)

CARD 4

The idea of succession is easy to grasp. It means simply that when a pond is first established, certain pioneer plants colonize its shores and later its bottom. Through the death and decay of these plants, the soil around and underneath the pond is enriched with organic nutrients that allow other, more demanding plants to appear. These plants, in turn, die and decay. Sediments build up and still different kinds of plants take root. As sediment accumulates, the pond becomes shallower and the shores reach in toward the center. The result, of course, is that the pond becomes smaller until finally its opposing shores meet and there is no longer any open water. The pond ceases to exist; it is now only a wet spot in a meadow and soon that too fills in and dries. (FLIP CARD)

CARD 5

And so your pond is gone. In its place is a lush green meadow that has its own patterns of succession. The meadow will continue to change for many years to come, going from a grassland to a thicket of shrubs, or to various communities of trees and finally to a "climax" forest. This "climax" forest, as the name indicates, will remain unless disturbed by changes in climatic conditions or other severe natural phenomenon.

Remember, a lake seen today is only an event in time, a moment in a sequence that reaches into the past and extends into the future. A lake has its birth, its youth, its maturity, its old age, and finally its death. A lake can exist for thousands of years if it is large and deep, but a small pond may appear and disappear in less than a century.

Let's examine a hypothetical curve of eutrophication by means of a line graph. (FLIP CARD)

CARD 6

The "x" axis, the bottom horizontal line of the graph, indicates the relative age of the lake. Here on the left is a point in time when the lake was born. The "y" ordinate, the vertical line on the left, indicates the "production of organic matter per unit area of lake surface."

There is a definite relationship between biological productivity (for the production of organic matter) and the relative age of the lake.

There are two features of the curve which are of major importance. First, it should be noted that during the initial aging phase of a lake there is a gradual increase of productivity. However, when the lake has gone through the oligotrophic and mesotrophic stages and enters the eutrophic phase, the rate of biological productivity shifts dramatically upward and gets much larger in a short period of time.

Second, the lake's almost immediate shift toward extinction due to artificial enrichment should be noted. What this means is that a lake may seem to be well and may not be changing very much, but if its age puts it close to the upturn point on the curve, only a very small increase in enrichment can cause death of the lake.

If a lake does not appear to be doing well (late stages of eutrophication) note how added enrichments at this stage cause almost sudden death. (FLIP CARD)

CARD 7

Another important influence on the aging of lakes is the occurrence of stratification of the waters within the lake. When a lake stratifies it separates into two or more layers which remain unmixed until some event forces a change.

Starting with a lake in which the water is the same temperature throughout, we can describe the establishment of thermal stratification. The wind blowing across the surface of a lake mixes oxygen from the atmosphere or circulates the water to a depth which is primarily dependent upon the average wind velocity. (FLIP CARD)

CARD 8

In the spring of the year, the air over the water becomes warmer than the water. The portion of the lake which is circulated by the wind is exposed to the air and becomes warmer. In this manner a zone or layer of warmer water is formed on top of the cooler uncirculated water. The warmer water is less dense than the cooler, weighs less for equal volumes, and thus floats on top of the cooler water. The result is the creation of a zone of stagnant water on the bottom of the lake.

What happens next is that plants and animals which die in the lake, along with introduced organic material, settle to the bottom of the lake to decompose. The organisms which decompose this organic material breathe oxygen and take it from the water. However, this water is stagnant and therefore cannot get to the surface of the lake and to an exposure to air for a new supply of oxygen. The stagnant layer becomes devoid of oxygen. In the absence of oxygen, chemical conditions become favorable for the release of nutrients from the bottom sediments into the surrounding water. (FLIP CARD)

CARD 9

When fall comes, the air temperature falls and the top circulating layer of water begins to cool. Eventually, the top layer becomes cooler and denser than the bottom stagnant layer. As the surface layer sinks to the bottom of the lake, it forces the nutrient-laden water to the surface. This internal recycling of nutrients can be very significant since it means that one load of nutrients can cause recurring problems year after year.

This phenomenon, called "overturning," does not occur in all lakes. Lake Okeechobee, for example, is very shallow, and all available information has failed to show the presence of any stratification. Apparently, the lake is shallow enough that the surface wind-mixed layer extends to the bottom of the lake. (FLIP CARD)

CARD 10

Nutrients result in high productivity and having established the meaning of eutrophy - "well-nourished" - the consequences of the abundance of nutrients become important. Under these conditions biological productivity becomes high. Plants (especially algae) react strongly as they float in the water in direct contact with the nutrients. Algae become primary producers of new organic matter upon which aquatic life depends. With algae being the base of the food chain, the basic problems of eutrophication can be evaluated in relation to the production of algae.

The form of algae which is of the most concern is the phytoplankton (plant wanderers). Phytoplankton are usually similar in all eutrophic lakes, but will vary quantitatively and qualitatively from one lake to another and will vary seasonally in any particular body of water. This is the result of the interaction of such factors as availability and types of specific nutrients, water temperature, light, and geographic location.

Lakes that are eutrophic usually have algal forms, called diatoms, during the low water temperature period in the fall, winter, and spring seasons; their numbers being greatest during the spring. In the late spring, green alga becomes dominant; then begins to die out with the arrival of the blue-green alga which is typical of the summer months, when the highest temperatures and greatest light conditions exist. With favorable conditions, blue-green alga is capable of producing enormous population explosions called "algal blooms." An algal bloom is the tremendous increase in the total number of algal cells in a given unit of water.

Their number increases to such an extent that their presence renders difficult the use of a particular body of water for its intended purpose.

The presence of algae is not a bad thing. In fact, without some algae a lake would lose a great deal of its use to man. Alga or phytoplankton forms the base of the food chain in lakes and other water bodies. Thus, certain quantities of algae are necessary to sustain good sport or commercial fishery in a water body.

The production of organic matter (phytoplankton) is one of the major consequences of eutrophication. Since these algae are plants, they contain chlorophyll. Sunlight acting on the chlorophyll in the process of photosynthesis utilizes carbon dioxide to build new plant tissue, and gives off oxygen as a by-product. When the algal cell count is extremely high, as it is during a bloom, sufficient oxygen is produced to create high levels of dissolved oxygen in the water body.

Normally high D.O. levels are desired and are an indication of clean water. In this case, however, a different condition exists and the high D.O. level during daylight hours tells another story. Plants, as well as animals, use oxygen in order to live. The photosynthetic production of oxygen requires daylight in order to occur. Consequently, when the sun sets, oxygen production ceases but plant respiration continues. The same mass of algae which created an excess of D.O. rapidly consume it until very low D.O. levels are reached in the water body.

Eventually, this mass of living plants complete their life cycle, die and decompose. An additional demand is placed upon the D.O. available in the water. As the alga decomposes, it releases a portion of the plant nutrient materials which it utilized to build cell tissue back into the water where it becomes available for continued algal growth.

These high nutrient levels cause other problems. (FLIP CARD)

CARD 11

This high biological productivity and dying continues until some change in the environment causes a halt in the wild growth of the algae. This change could be an exhaustion of some essential nutrient (see Appendix B), or merely a change in water temperature. The D.O. demands of living and decaying algae can pull D.O. levels to near zero, causing fish kills and severe odor problems. The dead fish in turn add still more decaying organic matter to the lake and create even greater oxygen demands on the overtaxed D.O. supply.

The decomposition of large amounts of organic material, under conditions of little or no dissolved oxygen, has a by-product several gases (methane, hydrogen sulfide, nitrogen dioxide, etc.) which have both unpleasant odors and physical effects. In extreme cases, lead-base house paints have been turned black by the gases given off from a eutrophic lake.

Certain members of the family of blue-green algae, typically present in algal mats, give off toxic substances during phases of their life cycle. These toxins have not been a health problem for humans for one reason: they create such an unpleasant taste in the water that it would be difficult to force enough of the water into an individual to cause any problem. Livestock, however, have been known to die from consuming too much of this water.

High nutrient levels which cause tremendous algal blooms may affect the specie community in the lake ecosystem. Less desirable fish replace sport fish such as the garfish replacing our large-mouth bass.

CARD 11 (Cont'd.)

The enriched algae-laden water can also cause problems for water treatment plants. The latter includes the clogging of filters, and bad tastes and odors in drinking water supplies, any or all of which would increase the costs of operation for these plants.

Over a period of years, the remains of the excess amounts of organic matter formed from stimulated plant growth tend to accumulate on the bottom of the lake in loose deposits. This material makes it difficult for desirable rooted aquatic plants to grow as they either are uprooted very easily by waves or else can never become established in the first place. This loose organic layer also becomes an impediment to those gamefish that need a firm bottom upon which to deposit their eggs.

Where does man fit into this complex scheme? (FLIP CARD)

CARD 12

Man is the cause of cultural eutrophication. Although eutrophication is a natural process, man's activities have had a great influence on the rate of the process. The altering of lake and stream drainage basins, urban and agricultural storm runoff, deforestation, and the discharge of municipal and industrial wastes have all contributed to the accelerated enrichment of our lakes and rivers.

ALTERING DRAINAGE - In 1970, engineers finished "channelizing" large stretches of the meandering Kissimmee River, speeding the flow of water into Lake Okeechobee and thus preventing flooding in Central Florida. But the by-passing of the loops made the stream travel so fast that water polluted by fertilizers and wastes rushed directly into the lake, threatening to "kill" it. A proposed remedy would reflood thousands of acres of cattle pastures in the shallow Kissimmee valley and restore them to marshy wet lands. The river would once again move more slowly and thus could cleanse itself before reaching the lake.

AGRICULTURAL STORM RUNOFF - Fertilizers contribute to the accelerated enrichment of our lakes and canals. Ammonia accounts for 90% of all nitrogen fertilizers used in the United States. Fertilizer entering receiving waters (after rainfall) is primarily dependent upon the degree to which a farmer controls his application rates and the season of the year when the fertilizer is applied.

<u>DEFORESTATION</u> - Nitrogen is one of the most important elements for plant growth. In its nitrate form, nitrogen is one of the most soluble compounds and is quickly leached out of soils and into ground or surface waters. For this reason, the change in the watershed by the cutting down of the forest often brings about an increase in nutrients in the surface waters (trees no longer absorb the nutrients).

Only those pollutants which contribute nutrients to the water add to the rate of cultural eutrophication. Nitrogen and phosphorous are usually considered the two prime nutrients necessary for eutrophication to occur. Caution is necessary when discussing removing either of these nutrients in order to control excessive algal growth or eutrophication.

<u>AVAILABLE SOLUTIONS</u> - There are several methods available for controlling the rate of eutrophication.

<u>Land use controls</u>, such as zoning practices and proper farming techniques, will serve to eliminate to a large degree the nutrients from these sources.

<u>Nutrient removal</u> from domestic and industrial waste water is possible by several methods.

1. The diversion of nutrient-laden water may offer help for a particular water body, but sometimes it may be at the expense of another. (Example - U.S. Army Corps of Engineers and the Kissimmee River.)

2. Weeds, algae, and fish may be harvested and thereby remove nutrients from the internal cycle of the system.

3. It may be possible to introduce members of the food chain which feed on large amounts of the nuisance algae and thereby reduce their numbers.

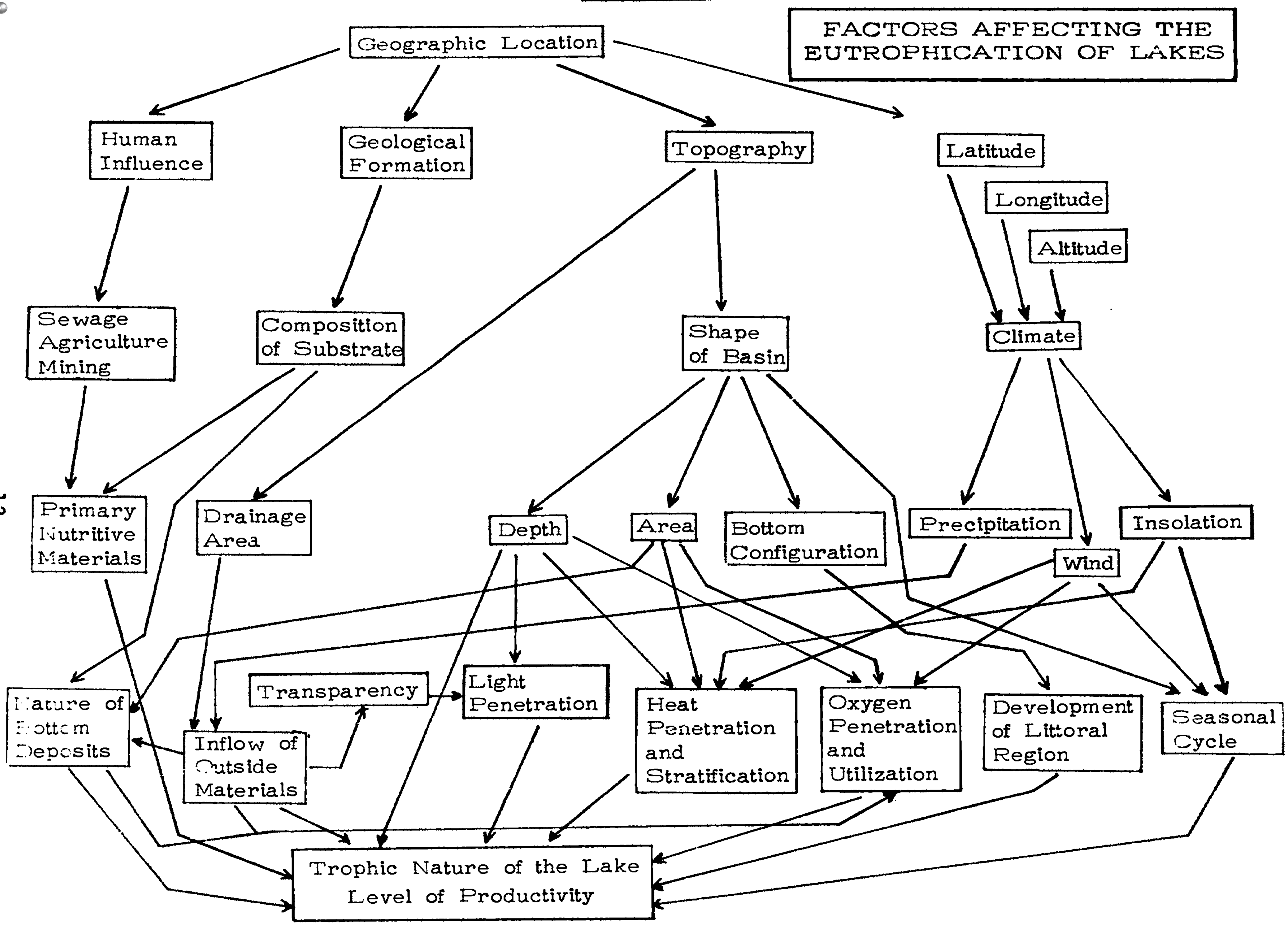
4. A smaller amount of light penetrating the water would reduce the source of energy for plants and thereby lessen their number and/or rate of reproduction.

5. Additional water could be added to a particular water body to dilute the nutrients during critical conditions of algal growth.

6. Dredging of sediments could deepen a lake but at the same time remove nutrient-laden organic sediments.

We have great impact on the rate of nutrient enrichment and eutrophication; and man, if he wisely gauges his actions, can probably slow this natural process and in some cases provide a measure of temporary relief from the undesirable effects of eutrophication.

APPENDIX A


FACTORS AFFECTING THE EUTROPHICATION OF LAKES
Geographic Location
Human Influence
Geological Formation
Topography
Latitude
Longitude
Altitude
Sewage Agriculture Mining
Composition of Substrate
Shape of Basin
Climate
Primary Nutritive Materials
Drainage Area
Depth
Area
Bottom Configuration
Precipitation
Insolation
Wind
Nature of Bottom Deposits
Transparency
Light Penetration
Inflow of Outside Materials
Heat Penetration and Stratification
Oxygen Penetration and Utilization
Development of Littoral Region
Seasonal Cycle
Trophic Nature of the Lake
Level of Productivity

APPENDIX B

ELEMENTS ESSENTIAL FOR THE GROWTH AND REPRODUCTION OF ALGAE

Element	Symbol	Minimum Requirements
(?) Aluminum	Al	Probably Trace Quantities
Boron	B	0.1mg/l
Calcium	Ca	20.0mg/l
Carbon	C	(Quantities Always Sufficient In Surrounding Medium)
Chlorine	Cl	Trace Quantities
Cobalt	Co	0.5mg/l
Copper	Cu	0.006mg/l
Hydrogen	H	(Quantities Always Sufficient In Surrounding Medium)
Iron	Fe	0.00065 - 6.0mg/l
Magnesium	Mg	Trace Quantities
Manganese	Mn	0.005mg/l
Molybdenum	Mo	Trace Quantities
Nitrogen	N	Trace Quantitles - 5.3mg/l
Oxygen	O	(Quantities Always Sufficient In Surrounding Medium)
Phosphorus	P	0.002 - 0.09mg/l
Potassium	K	Trace Quantities
Silicon	Si	0.5 - 0.8mg/l
Sodium	Na	5.0mg/l
Sulphur	S	Less Than 5.0mg/l
Vanadium	V	Trace Quantities
Zinc	Zn	0.01 - 0.1mg/l

APPENDIX C

Name________________________

PRE-POST TEST

EUTROPHICATION UNIT

Secondary School

DIRECTIONS: Circle the letter of one answer which best completes each of the following statements.

1. Overnourished waters are indicative of

   (a) high levels of biological activity
   (b) dead lakes
   (c) aging of a lake through the natural process of eutrophication
   (d) good fishing grounds

2. A simple definition of eutrophication is

   (a) a release of essential trace elements by decomposers
   (b) the interrelationship of bacteria and organic matter
   (c) the process of enrichment with nutrients
   (d) sediment build-up of lake bottoms

3. The "climax stage" in the ecological succession of a lake is characterized by

   (a) dry land
   (b) marsh or swampland
   (c) shallow lake depths
   (d) stratified water layers due to solar energy

4. Enrichment of a lake increases as it gets older due to

   (a) decomposition of dead organic matter
   (b) inflow of nutrient-laden water from surrounding drainage basins
   (c) rainfall
   (d) all of above

5. The extinction of a lake is a process of

   (a) enrichment
   (b) biological productivity
   (c) decay and sedimentation
   (d) all of above

6. The effect of artificial enrichment in a lake

   (a) decreases biological productivity
   (b) hastens "extinction time"
   (c) slows the natural process of eutrophication
   (d) increases D.O. (dissolved oxygen) content

7. Cultural eutrophication may best be described as

   (a) cultivation of freshwater green plants in greenhouses
   (b) a natural process
   (c) an unnatural process
   (d) circulating surface currents of a lake

8. Consider the following three statements.

   When examining a graph showing a hypothetical curve of eutrophication, it is clearly evident that

   Statement I - the rate of eutrophication proceeds at a uniform rate towards extinction

   Statement II - the initial aging phase of a lake shows a gradual increase in productivity

   Statement III - a small increase in enrichment during the eutrophic stage can cause a sudden significant shift towards extinction

   (a) I and III only
   (b) II and III only
   (c) I and II only
   (d) I, II and III

9. There is evidence that Lake Okeechobee was formed by

   (a) glacial action which formed depressions on the land surface due to tremendous weights of ice
   (b) geologic faulting which tilts land surfaces to form lake basins
   (c) crustal formations in which mountains have been thrown up to form basins
   (d) depressions created by crustal movements on the sea floor which were uplifted to form land

10. A cause of thermal stratification . be described as

    (a) D.O. (dissolved oxygen) depletion
    (b) recurring excessive fish kills due to algal blooms
    (c) heat differences between the water and air
    (d) a zone of warm water meeting cooler water

11. Eventually, algal blooms

    (a) decrease D.O. (dissolved oxygen) content in a lake
    (b) increase D.O. content in a lake
    (c) benefit fish who feed upon these organisms
    (d) deplete available carbon dioxide content in the atmosphere

12. The creation of a zone of stagnant water on the bottom of a lake would most likely be found in

    (a) lakes similar to Lake Okeechobee
    (b) the warmer seasons of the year
    (c) cooler seasons of the year
    (d) all lakes

13. The phenomenon called "overturning"

    (a) simply describes the process of sedimentation dredging
    (b) relates to a change in specie domination in eutrophied lakes
    (c) occurs in all lakes
    (d) describes the internal recycling of nutrients due to stratification

14. The presence of algal forms in a lake

    (a) render that particular body of water useless for its intended purpose (swimming, fishing, etc.)
    (b) should be avoided at all costs
    (c) has no ill effects whatsoever
    (d) are necessary in certain amounts to sustain good sport fishing

15. One may find that in a lake containing an algal bloom, oxygen

    (a) is largely consumed by the same mass of living organisms that produce them
    (b) is of relatively little concern to green plants which release oxygen as a waste product
    (c) has levels that are constant at all times
    (d) is utilized by green plants in daylight hours

16. Excessive amounts of organic matter found on lake bottoms as loose deposits

    (a) make it difficult for desirable aquatic plants to root
    (b) impede the deposit of eggs by game fish
    (c) liberate gases which have unpleasant odors when D.O. levels are low
    (d) all of above

17. The two prime nutrients necessary for eutrophication to occur are

    (a) nitrogen and oxygen
    (b) phosphorus and oxygen
    (c) potassium and phosphorus
    (d) nitrogen and phosphorus

18. The increased rate of eutrophication due to man's activities is termed

    (a) water budget degredation
    (b) hydrologic decycling
    (c) development of the littoral region
    (d) cultural eutrophication

19. A method of slowing the unnatural aging of a lake would be to

    (a) add more large mouth bass to the body of water in question
    (b) cut down shade trees on the shore of the lake to allow more light to penetrate the lake
    (c) divert nutrient-laden waste water away from the lake
    (d) allow for more "overturning" to suppress plant growth

20. Dead fish add more decaying matter to a lake and create

    (a) a great demand for oxygen
    (b) food directly for secondary consumers
    (c) ideal conditions in any lake ecosystem
    (d) none of above

APPENDIX D

TEST KEY (Eutrophication)

1. a
2. c
3. a
4. d
5. d
6. b
7. c
8. b
9. d
10. c
11. a
12. b
13. d
14. d
15. a
16. d
17. d
18. d
19. c
20. a

APPENDIX E

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