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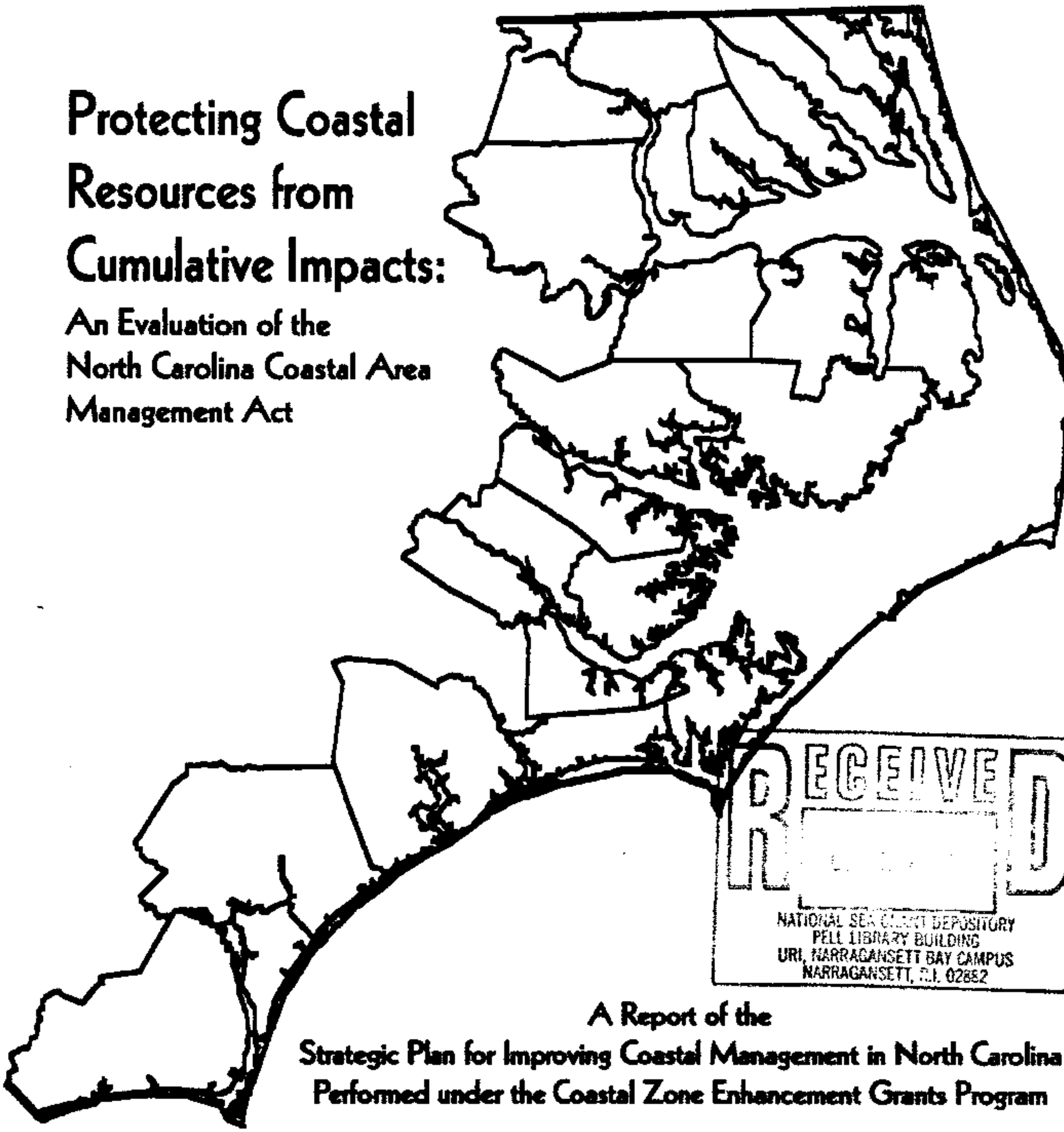
Protecting Coastal Resources from Cumulative Impacts:

An Evaluation of the North Carolina Coastal Area Management Act



A Report of the
Strategic Plan for Improving Coastal Management in North Carolina
Performed under the Coastal Zone Enhancement Grants Program

North Carolina Sea Grant College Program
Division of Coastal Management, N.C. Department of Health, Environment and Natural Resources

Protecting Coastal Resources from Cumulative Impacts:

An Evaluation of the North Carolina Coastal Area Management Act

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Table of Contents

I. Introduction..6-7

II. Cumulative Impacts..........................8-9

III. Recommendations........................10-27

Introduction..11

Geographic Area Needed for Protection of Coastal Environmental Quality..12

Maintaining the Estuarine Shoreline and Freshwater Riparian Buffers..............13

Critical Habitats..15

1. Seagrass Beds (and Shallow Sand)..16

2. Shallow Sand..16

3. Oyster Reefs (and Shallow Sand/Mud)..16

4. Salt Marshes (and Associated Nonvegetated Muddy Areas).........17

5. Fish Nursery Areas (Primary and Secondary)..17

6. Anadromous Fish Spawning Areas..18

Zoning..19

General Water Quality Management Recommendations..19

General Fisheries Management Recommendations..21

Land Use and Human Activity Management Measures..........................21

Municipal Wastewater Treatment Plants..21

Pulp and Paper Wastes..................22

Aquaculture..22

Boat and Barge Traffic..................22

Fishing Practices..23

Marinas..23

Seafood Processing..........................23

Land-disturbing Activities..............23

Agriculture (Cropland and Animal Facilities)..24

On-Site Waste Treatment/Septic Systems..25

Golf Courses..25

Residential Development and Commercial Development..............25

Industrial Sites..26

Hydromodification (Dredging, Stream Channelization, Etc.).........26

Wetland Alteration..........................27

IV. Implementation..........................28-41

Phase I: Immediate Changes to the AEC Structure..28

N.C.G.S. 113A-113(9) Areas of Environmental Concern; In General..28

N.C.G.S. 113A-118.2 Development in Critical Habitat Areas (Primary Nursery Areas) and Outstanding Resource Waters Areas of Environmental Concern..............29

N.C.G.S. 113A-120 Grant or Denial of Permits..29

15 NCAC 07H State Guidelines for Areas of Environmental Concern..29

Section .0205 Coastal Wetlands..............29

Section .0205(d) Use Standards..............29

Section .0206 Estuarine Waters..............29

Section .0206(d) Use Standards..............29

Section .0208(a)
General Use Standards 30

Section .0208(a)(6) 30

Section .0208(b)
Specific Use Standards..........30

Section .0209
Estuarine Shorelines.............31

Section .0602 Development
Standards Applicable to All
AECs.....................................32

15 NCAC 07K Activities in Areas
of Environmental Concern That Do
Not Require a Coastal Area
Management Act Permit...............32

Section .0400 Classes of
Federal Agency Activities
Exempted From the Permit
Requirement...........................32

15 NCAC 07M
General Policy Guidelines for the
Coastal Area.................................32

Section .0800
Coastal Water Quality
Policies...................................32

Phase II: Expanding Coastal Resource
Protection..32

N.C.G.S. 113A-103 Definitions.....32

N.C.G.S. 113A-115 Designation of
Areas of Environmental
Concern...33

15 NCAC 07H State Guidelines for
Areas of Environmental
Concern...33

Section .0503
Natural and Cultural Resource
Areas......................................33

N.C.G.S. 113A-118
Permit Required...........................33

N.C.G.S. 113A-120
Grant or Denial of Permits..........33

N.C.G.S. 113A-124
Additional Powers and Duties.....33

15 NCAC 07H State Guidelines for
Areas of Environmental
Concern.......................................34

Section .0205
Coastal Wetlands...................34

Section .0206
Estuarine Waters...................34

Section .0209
Estuarine Shorelines.............35

Section .0500
Natural and Cultural Resource
Areas.....................................38

15 NCAC 07K Activities in Areas of
Environmental Concern That Do
Not Require a Coastal Area
Management Act Permit..............38

Section .0208 Single-family
Residences Exempted...........38

15 NCAC 07M General Policy
Guidelines for the Coastal
Area..38

Section .0700
Mitigation Policies................39

Section .0800
Coastal Water Quality
Policies..................................39

Phase III. Sustainability and Land/Water
Use Planning.......................................39

V. References..................................42-44

Appendix A: Utilizing Coastal Resource Quality to Assess the CAMA AEC Management Structure..............A-1-A-38

Water Quality A-1

Problem Area I: Fish Kills and
Disease.......................................A-1

Problem Area II: Nuisance Algal
Blooms.......................................A-7

Problem Area III: Shellfish Contamination, Disease, Kills and Closure of Shellfish Beds..........A-8

Problem Area IV. Reductions in Fish Stocks..............................A-10

Problem Area V: Nursery Habitat Reduction................................A-13

Problem Area VI: Human Health Hazards...................................A-16

Literature Cited.........................A-18

Shellfish...A-21

Oysters...................................A-21

Clams......................................A-22

Blue Crabs...............................A-24

Shrimp.....................................A-26

Overall Function of the Benthic Community..............................A-28

Literature Cited.........................A-31

Fish...A-31

Turbidity.................................A-32

Oxygen....................................A-33

Temperature.............................A-33

Food Availability......................A-34

Habitat.....................................A-34

Salinity.....................................A-35

Currents (Flow/Hydrodynamics)...........A-35

Predators and Competitors........A-36

Fishing Mortality......................A-36

Disease.....................................A-37

Toxicants..................................A-37

Hormones.................................A-37

Conclusion..............................A-38

Literature Cited.........................A-38

Appendix B: Linkages Between Coastal Resource Quality and Land Uses and Human Activities.......................B-1-B-41

Introduction......................................B-1

Cumulative Impacts.........................B-2

Fish Kills and Disease.......................B-3

Nuisance Algal Blooms.....................B-4

Shellfish Contamination, Disease, Kills, and Bed Closure...............................B-5

Fish Stock Reduction........................B-6

Nursery Habitat Reduction................B-7

Human Health Hazards.....................B-8

Oxygen Deficit...................................B-9

Toxins in Water.................................B-10

Toxins in Sediment...........................B-11

Pathogens...B-12

Increased Nutrient Concentrations..B-13

Nutrient Recycling............................B-14

Food Chain Disruptions...................B-15

Turbidity...B-16

Hormones...B-17

Hydrologic Imbalances.....................B-18

Automobiles......................................B-19

Cropland...B-20

Animal Facilities................................B-21

Hydromodifications..........................B-22

Pulp Mills..B-23

Wastewater Treatment Plants...........B-24

Residential Development........B-25

Commercial Development........B-26

Golf Courses........B-27

Industrial Sites........B-28

Industrial Wastewater Discharges....B-29

Industrial Air Discharges........B-30

Mining........B-31

Forestry Operations........B-32

Marinas........B-33

Fishing Practices........B-34

Septic Systems........B-35

Road Building........B-36

Seafood Processing........B-37

Boat Usage........B-38

Construction........B-39

Wetland Alteration........B-40

Aquaculture........B-41

I. Introduction

Twenty years ago, North Carolina enacted the Coastal Area Management Act (CAMA) in response to the federal Coastal Zone Management Act (CZMA) of 1972. Since then, we have seen real benefits from effective coastal protection efforts, especially those that ensure public access, protect dunes and prohibit the construction of seawalls. But there is still widespread public concern over problems on our coast, which include nuisance algal blooms, fish kills and disease, and the closure of shellfish beds. These problems indicate that North Carolina's coastal management strategy is inadequately protecting coastal resources. After 20 years of rapid growth and development in the state, the North Carolina Division of Coastal Management (DCM) realized the need to evaluate how well the state's coastal management program protects resources against the cumulative impacts of this development. Consequently, addressing the cumulative and secondary impacts of development on coastal resources is a high priority enhancement area identified in North Carolina's CZMA Section 309 Enhancement Grant Strategy.

CAMA regulations apply to 20 coastal counties that border the ocean or a coastal sound. Through CAMA, the Coastal Resources Commission developed Areas of Environmental Concern (AECs) within the 20 coastal counties in the mid-1970s. The AECs are divided into four broad categories: the estuarine system; ocean hazard areas; public water supplies; and natural and cultural resource areas. The CAMA permit program applies to all development within the AECs, providing special protection for these areas. Although the use standards for AECs have evolved over the ensuing years and minor adjustments in the AEC boundaries have been made, the areas included as designated AECs have remained essentially the same. A survey indicated that there is widespread public concern over coastal water quality and loss of habitat for fish and wildlife in the Albemarle-Pamlico estuarine region (Hoban 1992). The Division of Coastal Management held public meetings on cumulative impacts in May 1993. They revealed a public perception that cumulative impacts of growth and development over the last 20 years have adversely affected coastal resources in spite of the AEC system established to protect those resources. As a result, the purpose of this study was to examine the adequacy of the AEC structure in protecting coastal resources from cumulative impacts.

DCM's cumulative impact public hearings also indicated that the impacts of greatest concern are those to coastal water quality, fisheries and shellfisheries. Therefore, these three resources were selected for the evaluation. The impacts to these three resources occur primarily in the four AECs included in the estuarine system category, including estuarine waters, coastal wetlands, public trust areas and estuarine shorelines. Therefore, the evaluation was limited to the adequacy of these four AECs and their use standards in protecting the environmental quality of the estuarine system. Since the project was meant to focus on environmental quality of coastal resources rather than on human-related issues such as use conflicts, the protection of public trust rights was specifically excluded from this study.

Realizing the need to base management measures on science, this study utilized the science community to make policy and management recommendations.

Scientists identified the protection needs of coastal resources, and policy experts reviewed the existing resource management structure. Together, they made recommendations to address the deficiencies within the management structure to protect the resources.

The evaluation process began with the assembly of a team of scientists with pertinent expertise for each of the three target coastal resources. Each team outlined the functions of its resource and determined the parameters that must be maintained for the resource to perform these functions. These parameters were then given to an environmental systems team (EST), which included scientists with expertise in evaluating and modeling the processes of the estuarine system of which the coastal resources are a component. The EST determined the geographic area and the management measures needed to maintain the parameters identified by the coastal resource teams. The current management structure for each AEC in the estuarine system category was reviewed. And finally, a team of coastal legal policy experts compared the EST's recommendations with the existing management structure. The recommendations that are already accomplished by the AEC structure and those recommendations that could be easily incorporated into the existing AEC structure without the need for significant legislative action were then identified. The policy/management team also provided advice for how to phase changes into the coastal management program to achieve effective protection of the target coastal resources.

Recommendations in this report include changes in the geographic AEC management area, changes in the types of activities that trigger CAMA permitting within the AECs and changes in the general and specific AEC use standards.

Section II (Cumulative Impacts) of this report provides an explanation of what cumulative impacts are, how they are affecting the resources on our coast and why we need to manage them. Section III (Recommendations) identifies various management approaches for addressing cumulative impacts and provides specific measures designed to protect important habitats from these impacts. They also are designed to reduce the contribution from specific land uses and human activities. Section IV (Implementation) presents a three-phase implementation strategy for making the necessary changes to our coastal management program to better protect resources from cumulative impacts. This section of the report gives specific recommendations to DCM and the CRC to accomplish these changes. The specific sections of the current CAMA regulations through which these changes should be implemented have been identified. Appendix A includes the coastal resource teams' reports, which describe the functions of the three target resources — fish, shellfish and water quality — and the parameters that must be maintained for the resources to perform their functions. The information in these three reports is the basis for the management strategy selected. Appendix B contains 40 diagrams that outline the linkages between cumulative impacts and the various human activities and land uses that cause them. These diagrams are designed to aid in targeting the appropriate land uses and human activities when designing a management plan to address a particular water quality problem.

II. Cumulative Impacts

As the pressure to build along the coast continues to increase, North Carolina faces the challenge of dealing with the cumulative and secondary impacts of this growth. Cumulative impacts are often described as impacts on the environment caused by development actions that may be minor standing alone but influence the environment significantly when added together over a period of time. Secondary impacts result when new development follows construction or improvement of infrastructure such as a highway, bridge, or water or sewer facility. Problems resulting from the combination of cumulative and secondary impacts are, by far, the most complex, since conclusive cause-and-effect relationships may be extremely difficult to identify.

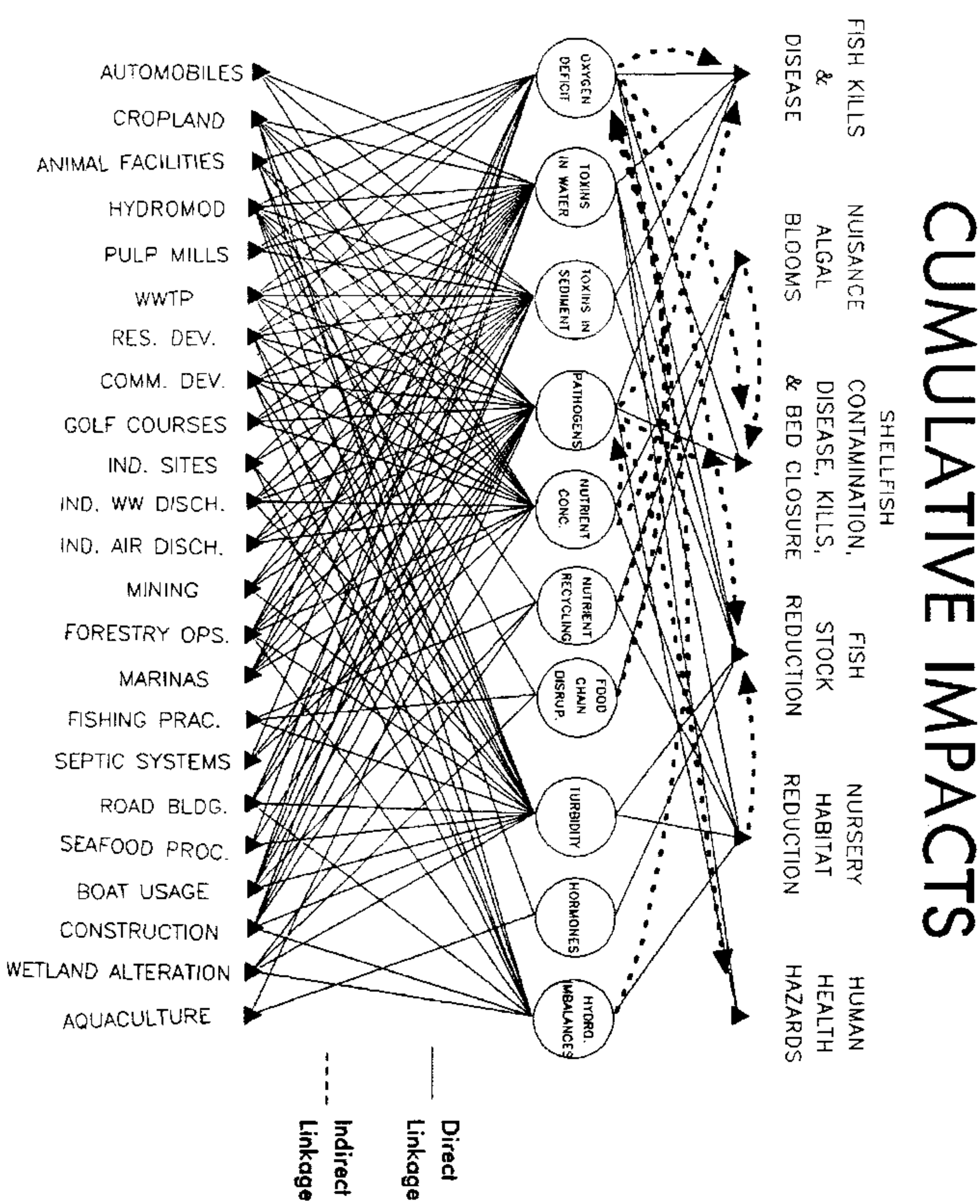
Cumulative impacts can be illustrated using a failing septic system as an example. If a single leaking septic tank is located on an acre of land near a tidal creek containing oysters, the impact of the leaking septic tank on the oysters, in terms of contamination by fecal coliform, may not even be identifiable. If 10 leaking septic tanks are located on the same acre of land and each tank leaks the same amount of contaminants, they can contribute enough fecal coliform bacteria to make shellfish beds unfit for harvest.

If the septic tanks were the only factor contributing to contamination, then identifying the problem would be relatively simple and management measures could be implemented. Serious problems arise, however, when many factors are present or when one factor triggers or enhances the negative effects of another. For example, significant land clearing and development within the area draining to the tidal creek removes vegetation that acts as a natural mechanism for filtering out and detaining land-based bacteria. The addition of this contributing factor makes it difficult to distinguish between the contamination from the septic tanks and that which is entering the water from overland runoff. This specific cumulative impact example can readily be seen on our coast and is evidenced by more than 56,000 acres of shellfish waters that are closed to commercial harvesting due to contamination. This acreage doubles when more beds are temporarily closed after prolonged heavy rain increases runoff and associated loadings of bacteria (Coastal Futures Committee 1994).

Secondary and cumulative impacts can also be exemplified by the symbiotic relationship between the fish-killing toxic dinoflagellate, *Pfiesteria piscicida*, and ulcerative mycosis, a disease affecting estuarine fish. In the case of Atlantic menhaden, the two fungi that cause ulcerative mycosis seem to be able to penetrate the fish through the lesions inflicted by the toxic dinoflagellate. The toxic dinoflagellate is stimulated by an increase in the amount of nutrients in the water. Therefore, geographically dispersed and seemingly inconsequential increases in nutrient loading may cumulatively result in a significant increase in overall nutrient concentration in the water. Over time, nutrient concentrations may reach a level at which the toxic dinoflagellate is stimulated and begins to attack the menhaden. Once attacked by the toxic dinoflagellate, the menhaden's resistance to disease lowers and the fish become highly susceptible to invasion by the fungi that cause ulcerative mycosis (Burkholder et al. 1995).

In designing a management strategy to protect coastal resources from the secondary and cumulative impacts of development, it is therefore necessary to first investigate all the known linkages between various land uses and human activities and current coastal problems. In determining the proper function of its resource, the Water Quality Team identified six problems that indicate degraded water quality and aquatic resource quality. The team listed all the known causes of and factors contributing to these six problems. The diagram presented as Figure 1 indicates the result of their evaluation. This diagram successfully shows the complexity of how all the activities of humans are cumulatively resulting in the changes that are considered environmental degradation.

Figure 1


CUMULATIVE IMPACTS
AUTOMOBILES
CROPLAND
ANIMAL FACILITIES
HYDROMOD
PULP MILLS
WWTP
RES. DEV.
COMM. DEV.
GOLF COURSES
IND. SITES
IND. WW DISCH.
IND. AIR DISCH.
MINING
FORESTRY OPS.
MARINAS
FISHING PRAC.
SEPTIC SYSTEMS
ROAD BLDG.
SEAFOOD PROC.
BOAT USAGE
CONSTRUCTION
WETLAND ALTERATION
AQUACULTURE
OXYGEN DEFICIT
TOXINS IN WATER
TOXINS IN SEDIMENT
PATHOGENS
NUTRIENT CONC.
NUTRIENT RECYCLING
FOOD CHAIN DISRUP.
TURBIDITY
HORMONES
HYDRO. IMBALANCES
FISH KILLS & DISEASE
NUISANCE ALGAL BLOOMS
SHELLFISH CONTAMINATION, DISEASE, KILLS, & BED CLOSURE
FISH STOCK REDUCTION
NURSERY HABITAT REDUCTION
HUMAN HEALTH HAZARDS
Direct Linkage
Indirect Linkage

III. Recommendations

This section of the report is a compilation of recommendations developed by the Environmental Systems Team (EST) aimed at better protection of coastal water quality, fisheries and shellfisheries from the cumulative impacts of growth and development. For each resource category, an evaluation team was assembled. The three teams are the Shellfish Team, the Fisheries Team and the Water Quality Team. Complete reports for these three teams are contained in Appendix A.

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This section of the report includes recommendations that the Environmental Systems Team has developed for the Division of Coastal Management and the CRC to use in adjusting and improving the existing CAMA AEC management structure and other coastal management programs. The overall objective is to better protect coastal resources from the cumulative impacts of development. The step-by-step process for implementing these recommendations, including specific changes to the existing CAMA regulations, is presented in Section IV. In addition, suggestions for implementation of other necessary measures outside the purview of the Division of Coastal Management are also provided.

Introduction

An estuary can be defined as a semi-enclosed coastal body of water that has a free connection with the open ocean and within which seawater is measurably diluted with fresh water derived from land drainage (Frankenberg 1993).

Long-term circulation in estuaries is often density-driven, resulting from the differences between river and ocean water. In an estuarine system, river water draws seawater upward from below and carries it downstream toward the ocean. To replace this outflow, seawater moves into the estuary. Thus, the effect of estuarine circulation is to draw subsurface, high-salinity water into the surface layer, which is essentially an upwelling process (Gross 1987).

Due to estuarine circulation, various processes occur in different parts of the estuary. The settling of sediments, for example, is closely tied to the character of estuarine circulation and is a fundamental process in controlling the flow of sediment between continents and oceans. Particles the size of sand settle from suspension as flow velocities decrease. Finer material, particularly clays, tends to flocculate as freshwater mixes with salt water; that is, the particulates aggregate as electrolytic forces bring them together. As these floccules increase in size, their settling velocity increases and they are deposited. Salinities of 2 to 5 parts per thousand are believed to be sufficient to cause such flocculation. Organic aggregation also seems to be an important process. These processes are responsible for the deposition of finer material within the estuarine system rather than their transport out of the estuary into the open ocean (Kennett 1982).

North Carolina's Estuarine Systems

In North Carolina, these edge systems were formed by a rise in sea level which began about 17,000 years ago and resulted in the drowning of the flat river valleys of the coastal plain (Copeland and Steel 1991). During this time, the sedimentary and physical character of the present sound system began to be defined. Today, the uppermost layer of unconsolidated sediments has the greatest effect on the modern estuary, dictating the general characteristics of the estuarine margins, bottoms, topography, soil types, water drainage and use of adjacent lands.

The climate of North Carolina's coastal region is moderately mild and moist, generally receiving 47 to 56 inches of rain per year. Temperature is also moderate, ranging from an average of 45 degrees Fahrenheit in January to over 90 degrees Fahrenheit in July and August. Winds are predominantly from the south-southwest with average velocities of 9 to 10 miles per hour. But extreme spatial and temporal variations in each parameter often have enormous effects on system processes.

The marginal water bodies of North Carolina are shallow relative to areal extent. They consist of coastal lagoons (Core Sound and Bogue Sound) and river mouth estuaries (Neuse River, Pamlico River, Albemarle Sound and Pamlico Sound). These waters are protected from the open sea by barriers, and their circulation and mixing activity are influenced by winds rather than lunar tides (Neumann 1993). Albemarle Sound and, to an even greater extent, Currituck Sound are connected to the ocean only through Croatan and Roanoke sounds via Pamlico Sound. They are strongly influenced by freshwater inflows and only marginally influenced by the Atlantic Ocean. Of the approximately 17,000 cubic feet per second (cfs) net, annual average freshwater inflow to Albemarle Sound, over half (8,000 cfs) is from the Roanoke River. In contrast, Pamlico Sound is connected to the ocean through several inlets that exert considerable oceanic influences upon the system.

Major sources of freshwater into Pamlico Sound are Albemarle Sound (17,000 cfs), the Pamlico River (5,400 cfs) and the Neuse River (6,100 cfs) with a total inflow of 31,700 cfs (Copeland and Steel 1991).

In the Albemarle-Pamlico system, wind is the most important factor driving short-term circulation; tides and freshwater inflows play secondary roles. Since the embayed lateral tributaries are very responsive to wind tides, winds blowing downstream may drive most of the water from the embayment, often eliminating any vertical stratification.

Evaluation Process

Estuarine water quality should be maintained at a level suitable to protect human health, recreational uses, fisheries, shellfisheries and other important coastal resources. This document is a compilation of recommendations developed by the Shellfish Team, Fisheries Team, Water Quality Team and Environmental Systems Team (EST). It is aimed at protecting North Carolina's coastal resources, namely water quality, fisheries and shellfisheries.

The Fisheries and Shellfish teams were charged with identifying the specific habitat needs and environmental conditions required by their respective resources. The Water Quality Team then identified the water quality conditions contributing to degradation of North Carolina's coastal resources. In addition, the Water Quality Team identified the primary causes and factors that contribute to estuarine water quality impairment. The EST then used this information to identify specific management measures to address the various land uses and human activities that were identified as contributing to coastal resource degradation.

The management measures recommended by the EST are designed to minimize the impact of human activities and land uses on coastal resource quality. Even if all these management measures are implemented, at some level of development the cumulative impacts of development will cause the resources to stop functioning. These measures can only minimize the impact; they cannot eliminate it. The management measures will help to maximize the amount of development that can take place without losing our valuable coastal resources. The question, therefore, is what is the maximum limit of development that should be allowed and what should it be based on? Schueler and others have provided correlations between urban stream degradation and amount of impervious cover based on various biological parameters, with most studies showing significant declines at as low as 10 to 20 percent watershed imperviousness (Schueler 1994b).

North Carolina's Water Supply Watershed Protection Act has specified limits on impervious surface for development within the five categories of water supply watersheds. The water supplies are categorized according to their use and the amount of development existing in the watershed, with less developed watersheds receiving the highest level of protection. For three of the categories, the regulations specify stricter requirements pertaining to density limits, buffer widths and stormwater controls for the portion of the watershed that immediately surrounds the water supply. This area is referred to as the critical area of the watershed (Eaker 1992). This protection approach may prove effective for some coastal resources.

Geographic Area Needed for Protection of Coastal Environmental Quality

The major rivers of eastern North Carolina carry significant quantities of freshwater along with dissolved and attached particulate matter, pathogens, metals, nutrients, pesticides and a host of other pollutants. For this reason, it is important to understand the extent and degree to which the rivers affect environmental quality in North Carolina estuaries. Based on a preliminary literature review, we have determined that river discharge does have a significant impact on estuarine resource quality. Therefore, upstream land-based activities that contribute to downstream environmental degradation should be regulated by the same management measures applicable to activities directly impacting the estuarine system. In North Carolina, river contributions of fresh water, metals, nutrients and toxicants are of particular concern.

The following examples support this finding:

"Maintenance of an acceptable level of estuarine water quality is dependent, to a large extent, upon the quality of the inflowing rivers. Rivers supply the estuary with freshwater, nutrients, sediments, and other substances. Estuarine water quality management must involve a knowledge and management of these riverine inputs." (Copeland and Steel 1991)

"A wider variety of metals are also discharged to the Albemarle estuarine system via the Roanoke River basin and Neuse River basin at higher loading rates than those discharged to the Pamlico River basin." (Cunningham 1992)

"Mercury may have entered the [estuarine] system from both point source discharges and nonpoint source discharges. Several pulp and paper mills in the A/P Study Area may have released mercury, which historically has been used as a fungicide at many U.S. pulp and paper mills." (Cunningham 1992)

"Total freshwater inflow from natural drainage basins within the Albemarle-Pamlico peninsula is probably not significantly changed by man's efforts to alter land use, but man's use of the drainage basins changes the rate of freshwater discharge into the receiving waters." (Pate 1981)

"Rapid pulses of freshwater appeared to be a dominant stress of juvenile organisms." (Pate 1981)

"Turekian et al. (1980) concluded that 'a strong correlation exists between high metal concentrations in all components of the coastal system (water, sediment, and organisms) and the proximity of polluted freshwater stream and sewer discharges.'" (Riggs 1993, 1990)

"...many small industrial municipal operations have point source discharges with potential for containing specific trace elements and producing localized or cumulative impacts upon the estuarine system." (Riggs 1993, 1990)

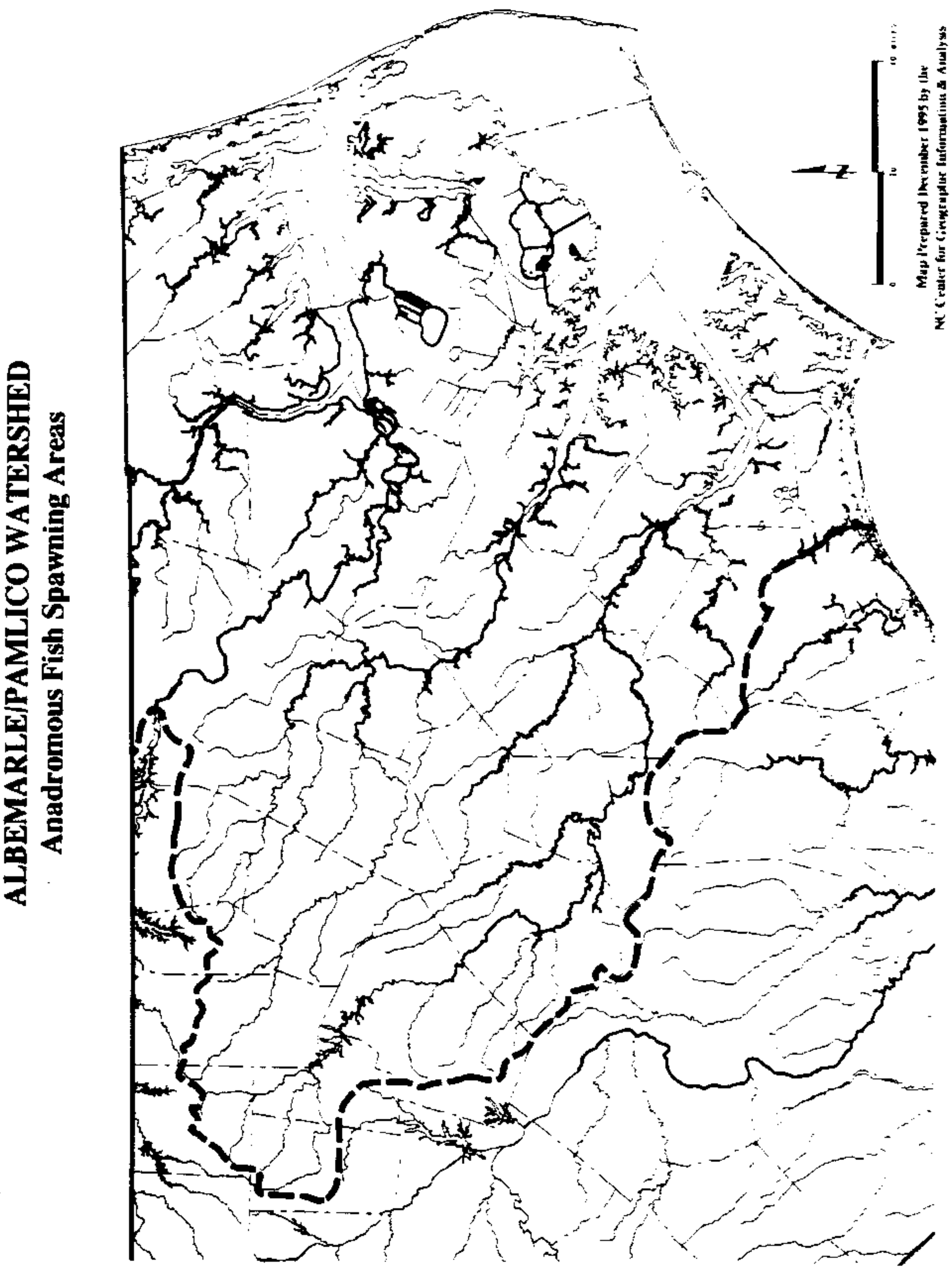
"The importance of a system-wide strategy in effective resource management has been emphasized in the CCMP...effective management of water resources ultimately relies on the consideration of system-wide processes and the cumulative impacts of activities across a river basin." (Waite et al. 1994)

Because of the influence of river flow on estuarine water quality and the extent of upstream migration by anadromous fish for spawning (Figure 2), ***the management measures selected by the EST for the various land uses can not be restricted or limited by political boundaries and should be applied to North Carolina's entire coastal watershed***. Unfortunately, many of the recommendations cannot be incorporated into the existing AEC management strategy. Some apply to areas outside the 20 coastal county region; others may not be able to be incorporated into North Carolina's coastal management program because of the Division of Coastal Management's jurisdictional limits. However, these measures are necessary in order to adequately protect coastal resources — i.e. fish, shellfish and water quality. The Division of Coastal Management can pursue many of these recommendations through coordination with other state and local agencies such as Sea Grant and the N.C. Cooperative Extension Service. This report will also provide suggestions for implementation of measures outside the existing AEC system.

Maintaining the Estuarine Shoreline and Freshwater Riparian Buffers

In addition to across-the-board land management measures throughout the entire coastal watershed to protect estuarine water quality, there should be buffers around the immediate shoreline of the estuaries and the rivers and their tributaries that feed the estuaries. The buffer for the estuarine shoreline is already established through the Estuarine Shoreline AEC; however, this protection should be improved and extended inland to protect the main river segments that feed the estuary and that have a significant impact on the quality of our estuarine waters. Along freshwater rivers, riparian buffers help to filter runoff and shade the water, thus improving water quality. Vegetated buffers are often implemented to mitigate the effects of nonpoint source pollution by

Figure 2


ALBEMARLE/PAMLICO WATERSHED
Anadromous Fish Spawning Areas
Map Prepared December 1995 by the
NC Center for Geographic Information & Analysis
115 Hillsborough Street * (919)733-2090

removing pollutants from runoff through plant and microbial uptake, microbial degradation and conversion, physical trapping, and chemical adsorption (Desbonnet et al. 1994). Riparian buffers are reported to remove as much as 90 percent of sediment and nitrate and up to 50 percent of phosphorus (Gilliam 1994). Gilliam considers "riparian buffers to be the most important factor influencing nonpoint source pollutants entering surface waters in many areas of the USA and the most important wetlands for surface water quality protection" (Gilliam 1994). Riparian buffers are especially important along rivers that serve as anadromous fish spawning areas (Rulifson, personal comm. 1995). Therefore, the buffer should extend upstream to the point of identified anadromous fish spawning areas that are currently used and those that were historically used.

Development in these buffers should have limitations and be restricted to appropriate uses. Inappropriate uses in urban areas include pump-houses, sewage treatment plants, golf courses, campgrounds, timber harvesting, hydropower, roads/bridges, athletic fields and playground equipment (Schueler 1994a). Schueler suggests a three zone buffer system for freshwater streams in urban areas that includes a streamside zone, a middle core and an outer zone. The streamside zone should be at least 25 feet in width; it is designed to protect the physical and ecological integrity of the aquatic ecosystem. Therefore, it should be maintained as a mature riparian forest that provides shade, leaf litter, woody debris and erosion protection to the body of water. Stormwater channels, footpaths and a few utility and roadway crossings are the only activities and uses that should be allowed in this zone. The middle core extends from the streamside zone and varies in width depending on the 100-year floodplain, adjacent steep slopes and protected wetland areas, but should have a minimum width of 50 feet. The middle core also protects the ecological integrity of the stream and provides further distance between upland development and the body of water. This zone should also be maintained as a mature forest; however, some clearing may be allowed for stormwater management, access and recreational uses. The outer zone is the buffer's buffer, providing at least 25 feet between the middle core and any permanent structures or septic systems. This area is typically a residential yard with turf or lawn as acceptable cover, but homeowners should be encouraged to include trees and shrubs to increase the total buffer width (Schueler 1994a). The U.S. Forest Service also suggests using a similar three-zone buffer system for intermittent and permanent streams to optimize pollutant removal from cropland, grassland and pasture. (Welch 1991).

Nonregulatory programs such as land acquisition, tax credits, subsidies, transferable development rights and environmental education could be used to better protect riparian buffers (see General Water Quality Recommendations on page 19 for more detail on these programs).

Critical Habitats

In addition to guarding general estuarine water quality, we should protect special areas within the estuarine system that serve as critical habitats for fish and shellfish. The current AEC system with the added watershed management strategy is still too general to adequately safeguard critical estuarine habitats. These critical habitats include:

1. seagrass beds
2. shallow sand
3. oyster reefs
4. salt marshes
5. fish nursery areas (primary and secondary)
6. anadromous fish spawning areas

Special protection should apply not only to the habitat itself, but also to the surrounding area that influences the habitat's condition. These important habitat features should be mapped with GIS, and species utilization should be shown over time. Also, the criteria should be determined for delineating the area that influences the habitat. Development requirements could be stricter in the areas having a greater impact on the habitat, which is similar to the provisions of North Carolina's Water Supply Watershed Protection Act. Once these areas are identified, current land use should be evaluated and priority status should be given to implementing the management measures recommended by the EST applicable to the existing development. Other state and federal agencies have and are developing maps and information on these habitats and associated resources. Existing information should be evaluated and utilized whenever possible. Special attention should be given to scale, compatibility and uniformity of the maps for suggested regulation enforcement. Any of the listed habitats that are not already being tracked by state mapping efforts which are updated on a regular basis (at least every 5 years) should be addressed.

In identifying and mapping the six critical habitats and the area that influences them, the evaluators should not draw traditional habitat boundaries that ignore the importance of interrelation among areas of the estuary. For example, the seagrass community is not just the seagrass bed itself. For the seagrass community to continue its function, the surrounding mudflat areas used for forage and the channel that provides flow into the area must also be maintained. This interrelationship of the grass bed, the mudflat and the channel is extremely important from a management perspective. Below is a description of the important components of each critical habitat and the recommendations for protecting it.

1. Seagrass Beds (and Shallow Sand)

Protection of seagrass beds should apply to the shallow sand areas that immediately surround the beds and the associated currents and flow patterns. In the shallow sand areas, crabs forage for food and the flow patterns or currents facilitate the passive colonization of the beds by larval organisms.

Recommendations:

• Protection of seagrass beds should extend 10 meters from the edge of the grass bed. No direct disturbances should occur to the bed or to this surrounding shallow sand area.

• No activities should be allowed that interrupt hydrodynamics, increase turbidity or nutrient loading or interfere with other water quality parameters to an extent that significantly inhibits or terminates the habitat function of the grass bed or poses harm to the animals utilizing the bed.

• Nitrate levels should not exceed 50 micrograms per liter for grass beds located in areas with a salinity of 25 parts per thousand or greater in order to protect our dominant seagrass, *Zostera marina*, and other important plant species.

• Proposed developments or activities within the area of influence should be evaluated for their potential disturbance both during construction and long-term operation.

• All seagrass mitigation projects should include consideration for the context of the grass bed and its full suite of functions. Without an adequate shallow sand area and currents, reestablishment of grass beds for habitat will not be successful.

2. Shallow Sand

Expansive shallow sand areas are important for blue crab foraging, especially in the absence of grass beds. Depth is the key characteristic that makes these areas suitable for blue crabs. Areas of less than a half meter in depth are typically utilized by blue crabs, which translates to one meter mean depth in tidal areas. Sand grain size is important. In areas frequented by crabs, the sands are fine with a mean grain size of greater than 125 microns. Fine sands are more important than silts. By weight, these materials are 75 percent fine to very fine sands with typically one half of one percent organic carbon. Shallow sand areas are also important habitat for several clam species.

Recommendations:

• No net change in sedimentation and siltation should occur in shallow sand areas.

• No dredging, filling, channelization or other hydromodification project that results in significant change in depth or sediment makeup should be allowed in shallow sand areas.

3. Oyster Reefs (and Shallow Sand/ Mud)

Crabs forage two to five meters off the continuous margin of oyster reefs. Therefore, the shallow sand/mud areas surrounding the oyster reef should be protected. Oyster reefs consist of oyster shells and some percentage of bare sand. If there is too much bare sand, the area is merely scattered shells. Scattered shell is found throughout much of Pamlico Sound and does not provide habitat like an oyster reef. Continuous clusters of oysters as small as one square meter in size, however, have shown habitat usage. It is not necessary for these clusters of oysters to be alive to serve as habitat for fish, blue crabs and other shellfish.

The issue of the spatial changes in the location of oyster reefs over time as well as potential reasons is also important. Evidence, primarily anecdotal, suggests that in North Carolina, oyster habitats have been impacted primarily by fluctuating and permanently changing salinity patterns.

Recommendations:

• All clusters of oysters (dead or alive) that are at least one meter square in size with a continuous boundary should be protected. These reefs should first be identified and mapped. Some oyster reefs are more than 100 years old, while others last for only five years. The inventory of reefs should be updated accordingly.

• No development or activities that would disrupt, fragment or otherwise physically destruct these beds should take place. As with seagrass beds, this protection should extend to 10 meters outside the continuous boundary of the oyster cluster in order to protect the shallow sand/mud areas used by blue crabs for forage.

• Each project or activity within the area of influence to the reef should be looked at individually to determine if construction or long-term usage will disrupt flow, increase turbidity or alter water quality to an extent that buries the oyster bed, significantly impedes its habitat or food function, or poses harm to the animals utilizing the reef.

• A literature search of current recommendations for suitable temperature, oxygen and salinity ranges for oysters and clams should first be conducted.

• All mitigation projects should include consideration for the context of a bed to be established. Without an adequate shallow sand/mud area and flow supplied by currents, reestablishment of oyster reef for habitat or food will not be successful.

4. Salt Marshes (and Associated Nonvegetated Muddy Areas)

Salt marshes, as well as the nonvegetated muddy areas that surround them, are important to shellfish for habitat. High in organics and high in productivity, shallow mud areas have uses similar to the shallow sand areas of the estuaries. Secondary and tertiary channels of the shallow mud areas typically have a 1-meter mean water depth and are important primary nursery areas for crabs, shrimp, spot and croaker. Flushing, tidal patterns, water depth and oxygen are important characteristics that make these areas suitable as nurseries. The marsh thus functions as a refuge, both through shallow water channels and intertidal vegetation and by providing a source of detrital food.

Recommendations:

• No changes in depth of the muddy areas adjacent to salt marshes should be permitted. If depth is increased, the area is exposed to larger predators, which inhibits refuge for larval shellfish and fish.

• Accessibility of these areas is also crucial. An area may have a lot of production, but because of certain conditions such as temperature, oxygen or lack of physical access, shellfish may be excluded from the area.

• Each development or activity within close proximity to the area should be looked at individually to determine if construction or long-term usage will disrupt flow exchange, lower dissolved oxygen, alter water quality, or block channel entrances to an extent that impedes the habitat function of salt marshes and the associated nonvegetated muddy areas or poses harm to the animals utilizing them.

• No activities or development should be permitted that alter flow dynamics to an extent that interferes with detrital accumulation or growth of vegetation in marsh areas.

• Developments immediately upstream of marsh areas should not increase runoff to salt marshes and surrounding mud areas.

5. Fish Nursery Areas (Primary and Secondary)

The N.C. Administrative Code defines nursery areas as habitats "in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young finfish and crustaceans spend the major portion of their initial growing season." Shallow upstream areas of estuaries throughout the coast serve as important nursery areas for large numbers of juvenile spot, Atlantic croaker, flounders, shrimps, blue crab and other species (Noble and Monroe 1991).

Recommendations:

- No activities should occur that interrupt hydrodynamics, significantly increase runoff, increase turbidity, increase nutrient loading, inhibit access, alter salinity, reduce dissolved oxygen or interfere with other water quality parameters to an extent that significantly inhibits or terminates the use of the nursery area or poses harm to the animals utilizing the nursery area.
- Migratory and access routes should be considered in all habitat preservation, restoration and creation efforts.
- Land use practices (e.g. land clearing) should be managed to prevent summer runoff temperature increases greater than 2 degrees Celsius and winter decreases greater than 2 degrees Celsius.
- No disturbance of wetlands adjacent to the nursery area should occur.
- Activities that prevent water movement in shallow areas should be excluded. Major point source discharges, land uses or activities that generate potentially hazardous quantities of bacteria, nutrients, oxygen demanding wastes, total suspended solids, metals, pesticides, toxins or harmful hormones should not be located within or immediately upstream of primary or secondary nursery areas.
- The Division of Marine Fisheries (DMF) and the Marine Fisheries Commission (MFC) should be given review opportunity of any permits in fish nursery areas.

6. Anadromous Fish Spawning Areas

Anadromous species of fish depend on the upper, less saline and freshwater areas of the estuary for both their spawning and juvenile development. In addition, larvae and juveniles may use submerged aquatic vegetation (SAV) beds, both in the river during their downstream journey and in the estuary or nearshore marine environments during juvenile residence. As with shellfish beds, anadromous spawning areas are extremely important to the continued propagation of many types of marine species, even though they are not officially designated as primary or secondary nursery areas by DMF (See Water Quality report in Appendix A). Depending on species, including Atlantic and sharpnose sturgeon, alewife, blueback herring, American shad or striped bass, the key factors in maintaining anadromous fish spawning areas include: access, water delivery (both timing and quantity), water quality (sedimentation, oxygen content, etc.), water temperature, food supply and habitat structure (Bain and Bain 1982, Facey and Van Den Avyle 1986, Fay et al. 1983, Gilbert 1989, Hill et al. 1989, Van Den Avyle 1984). Dams, seconded by highway culverts, were found to be the most common obstructions in the Albemarle/Pamlico Estuarine System, preventing anadromous fish from accessing large areas of former spawning habitat (Collier 1989).

Recommendations:

- Protection of anadromous fish spawning areas should include the river segments used for spawning and the adjacent riparian area that provides shade to the water and food in the form of insects, which drop into the river and are consumed by juvenile anadromous fish, especially cluepeids (shad and herring). This protection should also apply to the upstream river and associated riparian area that has influence on water quality and water delivery to the spawning area.
- Shoreline projects should be constructed to avoid disruption of riparian areas, especially overhanging vegetation. Disturbances should not result in heating of water, reduction of dissolved oxygen or sedimentation to an extent that would suffocate or smother eggs or harm any life stage of fish.
- No hydropower or other water use and discharge activities should significantly disrupt water delivery with respect to quantity or timing. Both factors of discharge are important not only to spawning, but to the maintenance of downstream nursery habitats. For example, no holding of water followed by large releases that would disrupt spawning activities should occur.
- No reservoirs or hydropower facilities that allow for significant discharges of heated waters either upstream of or to spawning areas should occur. All reservoirs should include low drain systems designed to release cooler bottom waters when needed. If bottom waters are anoxic, resulting downstream dissolved oxygen

levels should be determined and oxygenation should be considered.

• No culverts, dams, logjams or other riparian cut-throughs should occur that would result in exclusion of fish from spawning areas. Mitigation projects should focus on restoration of access to historical spawning areas.

Zoning

Finally, more effective land and water use planning (including zoning) can be used to protect coastal wetlands, critical habitats, freshwater riparian areas, estuarine shorelines, estuarine waters, existing AECs and other important coastal resource areas. Planning and zoning techniques can be used to encourage development in areas that are environmentally suitable and to discourage development on sensitive lands and in sensitive waters. These tools can be used to include local needs and values in management decisions. They also encourage policy-makers at the state and local level to be future-oriented rather than reactive and crisis-oriented.

For example, traditional zoning classifications (i.e. urban, rural, agricultural, etc.) in watersheds could be expanded to include new overlay zones such as hypersensitive, sensitive or developable. Also, planning and zoning techniques should be expanded beyond the traditional land-based permits to include the waters and submerged lands of coastal rivers and sounds (Clark 1990). Hypersensitive areas should include critical habitats such as oyster reefs, seagrass beds or fish nursery areas. The area of influence for the critical habitat could contain zones of sensitive, buffer and developable land.

Use standards could be developed for each zone. For example:

• *The following may be allowed in hypersensitive areas (U.S. EPA 1992, 37):*

— outdoor recreation
— resource conservation
— fish and wildlife management
— research or restoration experiments that are non-degrading

• *The following are prohibited in hypersensitive areas (the charts in Appendix B can determine the activities that have been identified as contributing to the degradation of coastal resources (U.S. EPA 1992, 37-38)):*

— landfills
— dumping, excavating, dredging, draining, filling and bulkheading
— damming
— development (including commercial, residential and industrial)
— underground storage tanks
— sewage treatment
— hazardous chemical discharge
— animal facilities that are large enough to require registration with the DWQ

The following would require a permit in a hypersensitive area:

— public park establishment
— construction and maintenance of public utilities
— construction and maintenance of designated existing roads
— wetland maintenance projects

Project review criteria should be developed for each of these zones. If a proposed project is determined to have significant impact to a hypersensitive area, it should be restricted or strict mitigation procedures should be required. All land areas, not just AEC areas, should be zoned according to their uses and protection needs. In addition to existing hypersensitive areas, this zoning should also consider things that were once hypersensitive, such as fragile critical habitats that have been degraded.

Land-use and water-use planning of this nature could be used for the entire 20 county coastal area and beyond.

General Water Quality Management Recommendations

• Don't exclude waters from ORW or HQW status because they fall only slightly short (within 5 to 10 percent) on resource values required for the designation. Instead, assign these waters the supplemental classification and take measures to improve water quality to the required criteria.

• Establish surface water quality standards and carrying capacities necessary to maintain surface water use classifications.

• Establish/increase programs and/or incentives to transfer "critical area" properties out of private ownership.

• Establish quantifiable cause-effect

relationships between land-use activities and surface water quality. These effects should include acute as well as sublethal chronic impacts.

• For highly degraded waters where cause-effect relationships can be identified, establish a program for mandatory implementation of documented, highly effective best management practices (BMPs).

• In developable areas, create standards for both point and nonpoint discharges. Base these standards upon current scientific information, with major input from the scientific community directly involved with active research on impacts of these variables. Standards are needed for the parameters listed below:

— turbidity
— total suspended solids
— salinity
— dissolved oxygen
— biological oxygen demand
— toxins
— pathogens
— nutrients

• Use incidence of fish kills and disease as an indicator of system stress. Reduce cumulative impacts to mitigate stress. Develop a monitoring system that includes emergency response for off-hour kills so that the causative agents of kills can be more accurately evaluated at or near the time of death.

• Use biological indicators to determine hazardous levels of toxics instead of considering only sediment and water-column concentrations. For biological indicators, include fish, zooplankton and species representing the entire food web. For example, researchers could expose selected species to samples of riverine and estuarine water and sediments and observe their survival. Examine salinity, dissolved oxygen, pH and other factors simultaneously to determine if they are affecting survival. Monitor changes in reproduction, growth and behavior and other impacts. Also monitor tissue contents of various metals and toxins. Focus these measurements on tissues where organisms store the contaminants, such as the nervous system, liver and fatty tissues (lipids), rather than on fillets and other components that are selected because of concern for human consumption. Restrict use and discharge of metals, pesticides and other toxic or potentially toxic substances in the estuarine system. Require strict limits on any use of the materials and ensure proper nonpoint source pollution controls, monitoring and record-keeping (see Water Quality report, Appendix A).

• Credibility of "old-timers" should be accepted in areas where we have no other data from which to draw conclusions about changes in water quality condition and species utilization.

• Improve compliance with regulations designed to protect water quality. For example, use regulatory programs to ensure development activity compliance, including strong enforcement with increased fines that will be viewed as more than just "a cost of doing business."

• Use nonregulatory incentives to better protect coastal wetlands, riparian buffers and critical habitats. Nonregulatory programs include land acquisition, tax credits, subsidies, transferable development rights and environmental education. Federal, state and local governments and/or private nonprofit organizations (land trusts) can purchase threatened wetlands, removing them from direct threat. The land can be held by the purchaser or transferred to other parties with restrictive deed convenants designed to prohibit uses that are incompatible with the ecological balance of the area. Tax credits and tax exemptions provide financial incentives for wetland conservation. These methods can induce owners to donate environmentally sensitive areas to appropriate governmental entities or land trusts. Subsidies, on the other hand, are direct payments to property owners (farmers, for example) for not engaging in an activity that could be harmful to wetlands or other sensitive areas. However, financial resources available for subsidy payments are becoming increasingly scarce in this era of reduced budgets. Transferable development rights (TDRs) can be an effective nonregulatory tool. TDRs allow landowners to sell or trade their development rights to an environmentally sensitive parcel for development rights on other property that is less environmentally significant. Finally, environmental education is perhaps the most effective nonregulatory tool. It can produce long-term shifts in public attitude regarding the protection of environmentally sensitive areas, ultimately lessening the need for regulation. However, because education is a long-term process, regulation will continue to be a necessary tool for environmental protection.

General Fisheries Management Recommendations

• Reduce loadings of nutrients and oxygen-demanding wastes to the estuarine system, especially near key fisheries habitat areas (most areas of the estuary are, however, key fisheries habitat areas). Reduce the geographical extent, frequency and occurrence of anoxia and hypoxia.

• Prevent activities that restrict water movement in shallow areas.

• Use a multispecies approach to fisheries management that gives equal consideration to impacts on invertebrates and noncommercial/recreational fishes when establishing regulations.

• Closely track and monitor fish kills (see seventh bullet under General Water Quality Recommendations).

• The amount of available habitat is finite and has been excessively reduced. Modify the permitting process to increase available fisheries habitat through mitigation.

• Allow DCM to obtain review authority over certain Marine Fisheries Commission decisions. Also give DMF and the MFC review authority over DCM and DWQ decisions that affect fish nursery areas.

• Evaluate and monitor the potential effects on fisheries of natural hormones and those introduced by humans. Thoroughly investigate proximity of animal operations, animal processing plants and certain aquaculture facilities and the potential impacts of runoff from these facilities to important fish habitats.

Land Use And Human Activity Management Measures

This section contains a summary list of recommendations specific to various land uses and human activities developed by the Environmental Systems Team aimed at protecting coastal water quality, fisheries and shellfish resources. Several factors were identified by the resource teams as contributing to degradation of these coastal resources in North Carolina. Each of the factors identified as a primary contributor to coastal resource degradation is listed in bold, followed by a list of recommendations developed by the EST. These recommendations are intended to minimize or eliminate the detrimental impacts that result from each contributing factor.

Municipal Wastewater Treatment Plants

Waste minimization:

• Establish nitrogen reduction targets for various river basins and subbasins and mechanisms to see that they are achieved.

• Implement human population density control planning. Comprehensive, long-term projections of the relationship between human population density and estuarine water quality on a basinwide, subbasin and a localized scale will help local governments prepare for growth.

• Maintain and expand the phosphate detergent ban. The phosphate detergent ban should be maintained for domestic detergents and expanded to include industrial detergents. This strategy is more effective in freshwater systems where phosphorus is limiting, and may not be as effective in nitrogen-limiting estuarine waters. However, both nutrients should be controlled.

• Enhance industrial pretreatment. It is more economical and effective for industry to minimize the quantity of toxic substances resulting from an industrial process than to treat it at a municipal wastewater treatment plant. Require industries to phase out use of major toxic substances that harm sensitive coastal areas.

• Improve and promote water conservation. Reducing the overall quantity of water used reduces the amount ultimately needing treatment and reduces the need for new water supplies. Conservation reduces the need to divert ecologically important fresh water flows from estuaries. Mandate programs requiring water conservation and water reuse.

• Expand household hazardous waste reduction. Education and outreach to households can reduce the quantity of hazardous chemicals used and improve disposal practices. Improve frequency and extent of household hazardous waste collection at the county level.

Policy strategies:

• Research and implement nutrient trading. A system of buying and selling of pollutant discharge allowance quantities among point and nonpoint source polluters can be economical and reduce current overall pollutant loading levels. Limits should be set low enough to ensure that the trading process begins in the near future.

• Rely on strong standards and permits. Compliance measures would strengthen wastewater treatment by prescribing exactly how much of a pollutant a discharger is allowed to release. Standards should be developed by river segment or subregion for nitrogen, phosphorus, enterococci and other variables.

• Carefully examine alternatives such as effluent, user and product charges; tax differentiation; and subsidies. Use financial incentives and penalties to manage the amount of pollutants being discharged. Develop a strong integrated program with benefits that are returned to the regulatory program.

Engineered solutions:

• Reuse and recycle treated sewage wastewater and apply sludge over land. A potential way to minimize disposal requirements and reduce treatment costs is to reuse and recycle.

• Increase the efficiency of municipal treatment plants in removing nutrients. Better removal technologies can reduce the amount of nutrients being discharged into the estuarine environment. Mandate such technologies in Nutrient Sensitive Waters and require removal of nitrate as well as ammonia and phosphorus.

• Research and develop natural wastewater systems and constructed wetland treatment systems. Copying and utilizing the pollutant removal mechanisms of existing natural systems may prove both effective and economical. Artificial systems should not, however, be developed to replace natural wetlands that would be lost through increased development.

• Base treatment requirements on environmental conditions. Make the degree of treatment required of a discharger dependent upon the actual environmental status of the receiving body of water and associated parameters. For example, manage Nutrient Sensitive Waters with effective, enforceable mechanisms to reduce both total inorganic nitrogen and total phosphorus loadings.

• Develop and implement better ways to identify water pollution. Accurate, inexpensive and effective ways to identify bacterial, viral and pathogenic water contamination are needed. For example, other states have adopted enterococci as a standard. Potential usefulness of fecal coliphages should also be considered.

• Use appropriate wastewater treatment plant siting. Place new treatment plants in areas that can best handle the amount of effluent the plant will produce.

Pulp and Paper Wastes

Waste minimization:

• Eliminate chlorine bleaching procedures. Expand the use of oxygen or ozone bleaching procedures, or eliminate bleaching altogether.

• Promote paper recycling. Reduce the need for new sources of paper.

Treatment improvement:

• Improve treatment technologies to reduce nitrogen and phosphorus discharge amounts.

Aquaculture

• Continue with the existing DEM permitting requirement that addresses site alterations and pond construction.

• In pond review, also consider impacts to downstream habitats such as oyster reefs and primary nursery areas. If release of eutrophic or turbid water from the facility will negatively impact the habitat, modify pond location and/or operation. Deny permits if impacts are unavoidable.

Boat and Barge Traffic

• Expand the regulatory authority of the CRC and provide an avenue for assessing the impacts of boating to pristine, rare or natural areas.

• Identify and quantify the impacts of fuel docks on water quality due to releases of heavy metals, fecal coliform and other pollutants.

• Identify the impacts to water quality of discharges from two-cycle boat engines on a subbasin and localized scale.

• Provide signs that identify the location of submerged aquatic vegetation (SAV) to enhance protection of this habitat.

• Provide pump-out stations at marinas and require all boaters to use them. Educate boaters on the importance of using pump-outs and inform them of the pump-out locations.

Fishing Practices

• Improve the coordination among the DMF, DWQ, DCM and their respective citizen commissions.

• Provide an avenue for the CRC to work with the MFC in policy development.

Marinas

The North Carolina Administrative Code 15NCAC 07H Section .0200 defines a marina as "any publicly or privately owned dock, basin or wet boat storage facility constructed to accommodate more than 10 boats and providing any of the following services: permanent or transient docking spaces, dry storage, fueling facilities, haul-out facilities and repair service."

Marina development should be regulated in three phases of development for maximum preservation of habitat and water quality. These areas include preconstruction, construction and postconstruction.

Preconstruction:

• Determine alternatives (avoidance):

— Select location where least amount of impact will occur.

— Keep all priorities consistent with state interests.

— Select a location with a fresh interchange of water and good flushing rates to maintain local water quality.

• Consider any site-specific criteria when locating facilities.

• Minimize shoreline stabilization. For example, build out with docks instead of along the coast with bulkheads.

• Model the proposed marina to determine:

— local water quality impacts

— maximum acceptable number of boat slips

— location where the least effluent impacts will occur

— tidal effects and flushing rates

Design considerations:

• Combine nonpoint source and stormwater regulations into a comprehensive marina management program similar to that of the State of Rhode Island (U.S. EPA 1993, 5-33-34, 5-36-39.) Examples include:

— porous pavement to filter stormwater through layers of gravel and sand before entering groundwater

— catch basins with sand filters to collect and cleanse water from impervious surfaces

— constructed wetlands to trap sediment

— stormwater infiltration basin/trenches

Construction:

See recommendations for hydromodifications (page 26).

Postconstruction:

• Require pump-out stations and enforcement mechanisms utilizing marina license renewal fees. DCM should investigate and implement educational and enforcement strategies to increase use of pump-outs.

• Require mandatory dry-docking for repairs involving hazardous and toxic chemicals such as painting, sealing, solvent-based cleaning, antifouling coating and stripping. Locate maintenance areas to avoid exposure of chemicals to rainfall and runoff, and store and use chemicals in a manner that avoids exposure. Include a water collection and treatment system specifically designed for the contaminants. (Davis 1989, 5)

• Require dripless refueling systems. (Davis 1989, 6)

• Require proper hazardous waste storage and disposal.

• Monitor all marinas to determine if they are within performance standards.

Seafood Processing

• Continue with the existing NPDES and stormwater discharge permitting process managed by DWQ.

• Provide DCM and the MFC with all permit information obtained by DWQ.

Land-disturbing Activities (Construction, Road Building, Forestry Practices and Mining)

• In devising strategies for developing and inspecting land-disturbing pollution controls, consider expertise about aquatic communities along with expertise about runoff and best management practices.

• Require each forest industry to file land-use management plans indicating how the land will be used and managed and how impacts to receiving waters will be addressed.

• Evaluate construction projects to ensure proper implementation of both temporary and permanent erosion-control measures. Inspect temporary measures during project activity and inspect permanent management measures after project completion.

• Use an amendment review procedure to allow for flexibility in altering plans in case land management circumstances are changed (i.e. management goals evolve or natural disasters change the site situation). This procedure provides a mechanism to ensure that the changes are properly managed.

• Provide funding to perform plan reviews, permitting and site inspection at the local level with regulatory consistency and technical assistance provided by the state.

• Provide funding to support educational programs related to the impacts of land-disturbing activities on water quality and aquatic habitats and to support proper BMP construction, operation and maintenance.

• Provide training and certification at the state level in the use of BMPs and sedimentation and erosion-control methods through the Land Quality Section of the Division of Land Resources for developers, contractors, silviculturists and farmers.

• Improve databases for vegetation, hydrology, soils and topography on a statewide basis and make the information available to all sectors to support plan development. These databases should be made available on GIS systems.

• Require preconstruction meetings.

• Increase financial incentives for compliance:

— Establish plan and site review fees.

— Provide tax credits and other incentives for compliance.

— Increase fines for noncompliance.

— Allow for temporary work stoppages without court orders based on noncompliance.

— Require proof of financial viability for covered activity.

• Develop an educational program to inform the public about the dangers of sedimentation and the importance of erosion control. Establish a number for reporting violators (i.e. sites with improper or malfunctioning controls or no controls at all) and create effective off-hour procedures for addressing reported violators.

Agriculture (Cropland and Animal Facilities)

Currently, a small percentage of farmers are implementing best management measures in North Carolina. They receive technical training from the N.C. Cooperative Extension Service and the N.C. Department of Agriculture through the Agriculture Cost Share Program. In educating farmers, more emphasis should be placed on profitability to encourage better participation in best management efforts.

• Require each farm to file a land-use management plan that indicates how the land will be used and managed in a way that protects receiving waters.

• Identify individuals not currently participating in the Agriculture Cost Share Program and expand incentives for voluntary BMP implementation.

• Increase funding to provide technical assistance for BMP implementation.

• Correlate and rank BMP effectiveness with the land use and land resource.

• Tailor incentive programs to target BMP implementation based on documented effectiveness for given land use and identified water quality problems.

• Adopt and extend the Farmstead Assessment System to facilitate a "whole" farm environmental assessment on water quality.

• Implement an environmental assessment program on all farms in the identified coastal region to expand awareness of the potential risks to coastal water quality. Target farm trade shows, banks and fertilizer companies for expanded outreach and education regarding coastal water quality issues.

• Strengthen compliance and enforcement to detect and correct water quality violations resulting from nonpoint source pollution.

• Establish land use and animal density constraints consistent with targeted sustainability goals on a watershed or subbasin basis.

• Increase incentives for producers to adopt production practices that reduce chemical applications.

On-site Waste Treatment/Septic Systems

• Accelerate research, adoption and implementation of alternative on-site waste treatment BMPs. Evaluate the effectiveness of BMPs using expertise of aquatic ecologists as well as engineers and other technical experts.

• Establish wide-scale demonstrations and evaluation for site-specific, on-site waste treatment alternatives, considering an array of soil types and drainage situations.

• Increase awareness of the need for homeowners to conduct routine septic system maintenance.

• Expand waste management entity jurisdiction to provide routine inspection of all types of septic systems.

• Implement a policy requiring low-flow systems in critical areas.

Golf Courses

• Quantify the localized impacts of golf course development and management on coastal resources and water quality, including effects on aquatic communities.

• Establish effective BMPs to increase the environmental friendliness of golf course owners and managers toward coastal resources and water quality.

• Develop an incentive program to accelerate adoption and implementation of effective BMPs on courses.

• Create user awareness of the environmental costs of intensive golf course management and maintenance.

• Ensure through siting and permit processes that course development is consistent with basinwide and local water quality objectives.

• Encourage the development of golf courses in areas that are already disrupted or degraded, where the installation and proper management of a golf course could improve conditions of surrounding waters rather than degrade pristine areas.

• Encourage the use of treated wastewater for golf course irrigation, especially for developments that pair a golf course with residential housing and that have treatment works designed for domestic wastewater only.

Residential Development and Commercial Development

• Encourage local governments to adopt ordinances to minimize impervious surface (Schueler 1994b). Examples include:

— narrower road widths

— clustering of development to reduce road lengths (remaining open spaces should be maintained adjacent to surface waters);

— restrictions on layouts of subdivision cul-de-sacs and roadways to reduce impervious surface and encourage infiltration of stormwater

— use of pervious materials for driveways

— restrictions on the number of parking spaces per square foot of commercial development to match average daily use — not potential maximum — and requirements that all overflow parking be constructed using pervious materials

— more accessible alternative transportation such as pedestrian, bicycle and mass transit

• Require local governments to adopt ordinances and zoning to maintain freshwater riparian and estuarine shorelines. Develop guidelines for maintaining these buffers and educate landowners on the importance of the buffer, its appropriate uses and effective maintenance. Post signs to indicate the extent and location of all buffers.

• Establish and use specification standards for plan/activity evaluations:

— Base water quality standards on potential water quality classification, not on existing classifications.

— Require temporary and permanent remedial measures for addressing sedimentation and runoff.

— Base standards for effective minimum buffer widths, filter strips, setback requirements, constructed wetlands, on-site containment and filtration devices, and impervious/permeable paving ratios on pollutant removal and hydraulic containment capabilities and efficiency.

— Base development density standards for different land uses on proximity to surface water, groundwater, nearby estuarine resources, open space preservation and existing development.

— Increase flexibility regarding stormwater treatment efficiency and reuse, design specifications and temporary stormwater detention devices.

• Set minimum subdivision development plans at an accurate, appropriate, project-specific scale and include standards that address the following:

— topographic detail relative to project size

— existing site conditions and critical area mapping

— clearing limits (especially near wetlands and riparian buffers)

— activities scheduling

— material and equipment staging/storage areas

— temporary and permanent stabilization/erosion-control methods based on hydraulic/sediment calculations, not existing sedimentation and erosion standards

— maintenance/removal procedures for BMPs and other devices

— extensive monitoring, maintenance and performance reviews

• Improve databases for vegetation, hydrology, soils and topography on a statewide basis and make the information available to all sectors to support plan development.

• Provide funding to support both formal and outreach educational programs about the impacts of development on estuarine resources.

• Provide state training and certification to DCM field representatives, local public officials, the Land Quality Section of the Division of Land Resources, developers, contractors, silviculturists and farmers in the use of BMPs and sedimentation and erosion-control methods.

• Require preconstruction meetings between permit applicants and local public officials or DCM field representatives.

• Increase financial incentives for project compliance:

— Establish plan and site review fees.

— Provide tax credits for compliance.

— Increase fines for noncompliance.

— Allow temporary work stoppages without court orders based on noncompliance.

— Require proof of financial viability for covered activity.

• Utilize constructed wetlands for stormwater nutrient removal.

• Examine the possibility for a regional stormwater facility as a retrofit for already developed areas.

• Develop an information database of BMPs that are appropriate for the coastal environment. These BMPs may include, but wouldn't be limited to: wet detention ponds, wetland systems, vegetative practices and bioretention, sand filter systems and extended dry detention. The management of nonpoint source pollution should be based on watershed boundaries, not political ones. A systematic approach is needed that determines the effectiveness of optimally combined on-site and regional detention.

• Evaluate the feasibility of using riparian buffers on problem areas (areas contributing significant nonpoint source pollution).

• Create a retrofitting program for developed areas that enhances the existing runoff control structures or conveyance systems for water quality improvement. These include pollution prevention practices, open and natural channel retrofit, in-line and off-line retrofit, and existing BMP retrofit.

Industrial Sites

• Continue the NPDES Stormwater Permitting Program's strong focus on prevention by limiting the exposure of pollutants to rainfall and runoff.

• Utilize on-site controls and management strategies to minimize stormwater runoff and to maximize water reuse.

Hydromodification (Dredging, Stream Channelization, etc.)

• Implement preactivity management measures.

— Prohibit hydromodification projects within 10 meters of SAV beds, oyster reefs, shallow sand areas and adjoining nonvegetated sandy/mud area and salt marshes, and shallow muddy areas surrounding salt marshes.

— Time hydromodification projects so that impacts on migratory species are minimized.

— Determine the cost/benefit ratio of long-term cumulative impacts.

— Project must be water-dependent.

— Project should be sited such that impacts are minimized.

— All hydromodification projects must be consistent with state interests.

— Use mathematical or physical models to identify changes in hydrodynamics and consider flows necessary to enable organisms' accessibility to critical habitat areas.

— Consider standards for maintaining

water quality in Critical Habitat Areas, including oxygen deficit, toxins, pathogens, nutrients, turbidity, total suspended solids (tss) and salinity.

— Require preactivity sediment contamination testing for appropriate pollutants based on the site history and determine a sediment/soil contamination standard.

• Utilize the following activity-concurrent management measures:

— For noncontaminated soils, use a sediment-containing device such as a sediment curtain.

— For contaminated soils, sediment curtains or sediment walls may be required, and a watertight clam-shell (hinged) bucket should be used to remove contaminated material. (Palermo et al. 1989, 73; Sanderson et al. 1986, 24-25)

— Consider oxygen injection to raise DO levels. (Neal et al. 1977, 190)

— Dispose of drained water in areas with similar characteristics.

— Use submerged diffusers for release of noncontaminated spoil in AECs.

— Cap highly contaminated spoil and utilize diffusers when releasing less contaminated material.

— Use a Global Positioning System to locate exact disposal sites.

— Record the exact time, location, and weight of disposal.

— As an alternative to disposal, use noncontaminated dredge spoil for marsh creation; farmland application; commercial development; a substitute for sand on ice-covered roads; or ceramic products. (Landin and Smith 1986, 73-74)

— Use self-propelled, split-hull barges that do not leak material.

• Implement post-activity management measures:

— Schedule maintenance activities during times of low use by aquatic species.

— Use permit fees to help cover the costs of monitoring and remediation.

— Correct all hydromodification-related impacts.

Wetland Alteration

• Map all wetlands by type, including Critical Habitat AECs.

• Evaluate all wetlands according to indigenous species habitat, water characteristics, tidal flows, soil type and land use. Identify all wetlands that are included in a Critical Habitat AEC.

• Evaluate whether development activities would be in compliance.

• Determine the ratio of wetlands — created versus destroyed — for mitigation.

• Require payment and mitigation activities from the party responsible for wetland loss.

• Monitor mitigation sites for a minimum of 20 years to assess:

— species diversity;

— water levels;

— water quality.

• DCM should set up a fund, using permit fees, to help defray the costs of mitigation and monitoring.

• DCM should further identify effective wetland mitigation techniques.

• Revise existing 401 permitting program to include specific management measures.

• DCM should identify priority wetlands for restoration. These should include wetlands near critical habitat AECs, ORWs, HQWs or other important coastal resources, wetlands that would be most easily restored, and wetlands that are considered high value because of filtering capacity or habitat for endangered or threatened species. For example, high priority should be given to restoration of freshwater riparian wetlands along sloped riverine shorelines because of their water cleansing ability.

• Use nonregulatory programs such as tax credits, land acquisition, subsidies, transferable development rights and environmental education to prevent wetland disturbance and alteration.

IV. Implementation

*T*his section of the report details a three-phase process for implementing the recommendations determined necessary by the EST and the coastal resource teams to protect coastal resources from the cumulative impacts of development. A team of coastal legal policy experts provided advice in developing the implementation strategy for the management recommendations.

POLICY/MANAGEMENT TEAM

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The implementation of changes necessary to improve protection of coastal resources is broken into a three-phase process. The first phase involves identifying and mapping critical habitats within existing AEC areas, developing use standards to better protect these habitats and other changes to the AEC structure that can likely be made without significant changes in the CAMA permitting process. The second phase involves long-term changes in North Carolina's approach to protecting coastal resources. These changes involve managing coastal waters on a watershed basis, including expansion of CAMA's geographic area to protect all habitats critical to coastal resources and developing strategies for reducing pollution from sources currently not required to obtain CAMA permits or comply with other regulatory programs. Phase III involves evaluation of sustainability of our coast on a watershed, subbasin and critical habitat area basis and the incorporation of sustainability goals into county planning.

For Phases I and II, each recommendation is listed under the specific section of the existing CAMA regulations in which the change should occur. The section numbers correspond to either the North Carolina General Statutes (N.C.G.S.) or the North Carolina Administrative Code (NCAC).

Phase I: Immediate Changes to the AEC Structure

The coastal resource teams identified several habitats important to fish and shellfish that need special protection (see the EST recommendations in section III and the Shellfish Team report in Appendix A). Some of these critical habitats are geographically located within the existing Estuarine System AECs. Therefore, the use standards can be modified or additional use standards can be added to these AECs as a first step toward providing special protection for these habitats. Below is a list of recommended changes and alterations to existing use standards — as well as additional recommended changes that can be made to CAMA — designed to reduce pollution from a variety of land uses and activities and thereby better protect estuarine habitats and the resources contained within the existing estuarine AEC categories. All of the following changes apply to the CAMA regulations in the North Carolina Administrative Code (NCAC) and in the North Carolina General Statutes (N.C.G.S.).

N.C.G.S. 113A-113(9)
Areas of Environmental Concern; In General:

- Primary Nursery Areas should be changed to **Critical Habitat Areas** and should be expanded to include primary; secondary; special secondary nursery areas as defined by the North Carolina Division of Marine Fisheries; SAV beds (as updated in 15 NCAC 07H Section .0208 (6)); shallow sand areas less than one meter in depth; secondary and tertiary channels in shallow, muddy salt marsh areas less than one meter in depth; and oyster reefs greater than one square meter in size, with a 10 meter buffer of submerged shallow sand/mud areas immediately adjacent to the oyster reef.
- All Critical Habitats should be mapped using GIS. Species utilization should be shown over time. Special attention should be given to scale, compatibility and uniformity of the maps. Existing information should be used where possible. All habitats should be tracked and maps updated regularly (at least every five years).

N.C.G.S. 113A-118.2
Development in Critical Habitat Areas (Primary Nursery Areas) and Outstanding Resource Waters Areas of Environmental Concern:

In addition to primary nursery areas, the following should be included in Critical Habitat areas: secondary and special secondary nursery areas; SAV beds (as updated in 15 NCAC 07H Section .0208 (6)); shallow sand areas less than one meter in depth; secondary and tertiary channels in shallow, muddy salt marsh areas less than one meter in depth; and oyster reefs greater than one square meter in size, with a 10 meter buffer of submerged shallow sand/mud areas immediately adjacent to the oyster reef.

Additional use standards for these areas that have been identified as crucial to the survival and maintenance of a significant number of estuarine species, whether designated as Critical Habitat Areas or not, are listed in 15 NCAC 07H Sections .0205(d), .0206(d), .0208, and .0209(e)(f).

Outstanding Resource Waters AECs would remain subject to the development standards of this section and should be subject to the same use standards developed for Critical Habitat Areas listed in 15 NCAC 07H Sections .0205(d), .0206(d), .0208, and .0209(e)(f), including the use standards proposed by this study that appear in the following sections.

N.C.G.S. 113A-120
Grant or Denial of Permits

The responsible official or body should deny an application for a permit if it finds that the proposed development will violate the use standards developed for Critical Habitat Areas in Subchapter 7H, Sections .0205(d), .0206(d), .0208, and .0209(e)(f).

15 NCAC 07H
State Guidelines for Areas of Environmental Concern

Section .0205
Coastal Wetlands

Within the definition of Coastal Wetlands, salt marshes should be identified as "the area of marsh vegetation and the immediately adjacent submerged nonvegetated muddy areas with an average depth of one meter in tidal areas, and one half meter in non-tidal areas." Nonvegetated muddy areas containing secondary and tertiary channels less than one meter in depth should be considered Critical Habitat Areas. All subsequent references to "Salt Marshes" would refer to this definition.

The following areas, located within the coastal wetlands AEC, should be subject to the specific use standards listed for each resource in Section .0206(d) Estuarine Waters and Section .0208 Use Standards: primary, secondary, and special secondary nursery areas; SAV beds, shallow sand areas less than one meter in depth; secondary and tertiary channels in shallow salt marsh mud areas less than one meter in depth; and oyster reefs greater than one square meter in size, with a 10 meter buffer of submerged shallow sand/mud areas immediately adjacent to the oyster reef.

The following use standards should be added to better protect critical habitat areas within coastal wetlands.

Section .0205(d) Use Standards

- DCM should ensure that all suitable land uses for coastal wetlands do not:
  - — change the depth of the nonvegetated muddy areas adjacent to salt marshes;
  - — inhibit access to salt marshes; disrupt flow exchanges or hydrodynamics;
  - — lower dissolved oxygen levels;
  - — alter detritus accumulation;
  - — increase runoff and fresh water input.

Section .0206
Estuarine Waters

Critical Habitat Areas contain additional management requirements and use standards in order to preserve and protect estuarine resources. Proposed projects affecting Critical Habitat Areas should meet ALL new and existing use standards and be subject to public notice, opportunity for public comment and agency review.

The following new use standards should be added to better protect critical habitat areas within estuarine waters:

Section .0206(d) Use Standards

Nursery Areas/Shallow Secondary and Tertiary Channels in Salt Marshes

- Prohibit activities that increase water temperature by more than 2 degrees Celsius in summer or decrease water temperature by more than 2 degrees Celsius in winter.
- Prohibit major point source discharges, land uses or activities that generate

potentially hazardous nutrients, metals, pesticides, toxins, oxygen demanding waste, total suspended solids, bacteria or hormones within or immediately upstream of any nursery areas or salt marshes utilized as nursery areas.

SAV Beds (including 10 meters surrounding shallow sand area)

- Prohibit development that physically disturbs seagrass beds, including the 10-meter shallow sand perimeter area.
- Prohibit development that will result in, or contribute to, nitrate levels above 50 micrograms per liter in SAV beds with a salinity of 25 parts per thousand or greater.
- Prohibit projects resulting in a net change in sedimentation and siltation to shallow sand areas.
- Development must not restrict water movement in any shallow sand areas that are one meter or less in depth.
- Development must not measurably increase siltation in any shallow sand areas that are one meter or less in depth.

Oyster Reefs

- Prohibit any development activities or fishing practices that would disrupt, fragment or otherwise physically damage these beds or the adjacent 10-meter shallow sand/mud area.
- Prohibit projects that have been determined will disrupt flow; increase turbidity; alter water quality to an extent that buries the oyster bed; impede habitat or food function; or pose harm to species utilizing the reef.

Shallow Sand Areas

- Prohibit any development that will change the water depth or contribute to siltation or the lowering of dissolved oxygen in shallow sand areas.

Section .0208(a)
General Use Standards

Before being granted approval for a permit, there shall be a finding that the project meets all of the following parameters, in addition to those included in Sections .0205(d) and .0206(d):

- The development project must not interrupt hydrodynamics, increase runoff, increase turbidity or nutrient loading, inhibit access, alter salinity or violate, either directly or cumulatively, other identified water quality standards necessary for the proper functioning of Coastal Wetlands, Estuarine Waters and Critical Habitat Areas.
- The development must not increase loadings of oxygen-demanding wastes immediately upstream of Critical Habitat Areas.
- The project must not cause any direct disturbance, alteration or degradation of Critical Habitat Areas.
- The public benefits of development must clearly outweigh the long-range adverse cumulative impacts of development if it is found that the development violates any use standard.

Section .0208(a)(6)

Protection of SAV beds should extend outward a minimum of 10 meters or to a water depth of 1 meter, whichever is greater, in order to include adjacent shallow sand areas.

Section .0208(b)
Specific Use Standards
(1) Navigation Channels, (2) Hydraulic Dredging, (3) Drainage Ditches, and (4) Nonagricultural Drainage.

The first four activities listed under specific use standards could all be considered hydromodification. The following recommendations address all hydromodification activities including Navigation Channels, Hydraulic Dredging, Drainage Ditches and Nonagricultural Drainage.

- All hydromodification projects must monitor for dissolved oxygen, metals and toxicants, turbidity and other applicable parameters during and following completion of all hydromodification activities. Post-monitoring should continue until DCM has determined adequate site stabilization and associated impacts to be insignificant.
- All hydromodification projects must be a minimum of 10 meters from a Critical Habitat Area.
- Hydromodification projects must not violate the use standards listed in Sections .0205(d), .0206(d) and .0208.
- Hydromodification project design should avoid bulkheading in favor of vegetative shoreline stabilization or other more environmentally friendly techniques where feasible.
- Hydromodification projects should be subject to the following three-tiered system of use standards:

(1) Implement pre-activity management measures.

— Prohibit hydromodification projects within 10 meters of SAV beds, oyster reefs, shallow sand areas and nonvegetated sandy/mud area immediately adjacent to these areas, salt marshes, and shallow muddy areas surrounding salt marshes.

— Time hydromodification projects to minimize impacts on migratory species. DMF should be consulted for review in the case of large hydromodification projects.

— Use a cost/benefit determination of long-term cumulative impacts.

— Project must be water-dependent.

— Project must be sited to minimize impacts.

— All hydromodification projects should be consistent with state interests.

— Use mathematical or physical models to identify changes in hydrodynamics. Maintain flows necessary to provide accessibility to critical habitat areas.

— Oxygen deficit, toxins, pathogens, nutrients, turbidity, total suspended solids and salinity standards for maintaining water quality in Critical Habitat Areas should be considered.

— Require pre-activity sediment contamination testing. (DCM and/or DWQ should determine a suitable sediment/soil contamination standard for appropriate pollutants based on site history. The water quality standards should be designed to protect local water use classification.)

(2) Use the following activity-concurrent management measures:

— For noncontaminated soils, use a sediment-containing device such as a sediment curtain.

— For contaminated soils, require sediment curtains or sediment walls and use a watertight clam-shell (hinged) bucket to remove contaminated material.

— Consider oxygen injection to raise DO levels.

— Dispose of drained water in areas with similar characteristics.

— Use submerged diffusers for release of noncontaminated spoil in AECs.

— Cap highly contaminated spoil and utilize diffusers for release of less contaminated material.

— Use a Global Positioning System to locate exact disposal sites.

— Record the exact time, location and weight of disposal.

— As an alternative to disposal, use noncontaminated dredge spoil for creation of marsh habitat; farmland application; commercial development; a substitute for sand on ice-covered roads; and ceramic products.

— Use self-propelled, split-hull barges that do not leak material for transporting dredge spoil.

(3) Implement post-activity management measures:

— Schedule maintenance activities during times of low use by aquatic species.

— Use permit fees to help cover the costs of monitoring and remediation.

— Correct all hydromodification-related impacts.

(5) Marinas

Every effort should be made to locate marinas in waters with no identified Critical Habitat Areas and to be consistent with state and local interests. Marinas should be sited in locations with adequate flushing rates. Marina placement, construction and normally associated activities should comply with the use standards listed in .0205(d), .0206(d) and .0208. Marinas should be monitored to ensure they are within performance standards.

In addition, marina development applicants should provide plans that:

• include minimum shoreline stabilization and use vegetative stabilization measures when applicable (bulkheads should be avoided to the extent possible);

• minimize effluent impacts;

• determine tidal effects and flushing rates;

• combine nonpoint and stormwater controls into a comprehensive marina management program using techniques such as porous pavement to filter stormwater through layers of gravel and sand before entering groundwater; catch basins with sand filters to collect and cleanse water from impervious surfaces; constructed wetlands to trap sediment; and stormwater infiltration basins/trenches.

• require mandatory pump-out stations;

• require any repairs involving hazardous and toxic chemicals to take place at a dry dock;

• require dripless refueling systems;

• require proper hazardous waste storage and disposal;

• include monitoring to ensure compliance;

• include boater education and awareness programs.

(7) Bulkheads and Shore Stabilization Measures

(E) Where possible, vegetation and other low environmental impact techniques shall be used for shoreline stabilization rather than gabions and riprap. Prohibit vertical seawalls and bulkheads.

Section .0209
Estuarine Shorelines

Development considered suitable in the estuarine shoreline AEC under existing CAMA regulations must also follow all use standards included in Sections .0205(d), .0206(d) and .0208 to protect Critical Habitat Areas.

Section .0602
Development Standards Applicable to All AECs

No development shall be allowed in any AEC or Critical Habitat Area if it directly or cumulatively violates any use standard developed for the Critical Habitat Area or AEC as set forth in Section .0205(d) through Section .0208.

15 NCAC 07K
Activities in Areas of Environmental Concern That Do Not Require A Coastal Area Management Act Permit

Section .0400
Classes of Federal Agency Activities Exempted from the Permit Requirement

DCM should ensure that all federal activities excluded from acquiring a permit not violate use standards for, or at the least minimize impacts to, Critical Habitat Areas.

15 NCAC 07M
General Policy Guidelines For the Coastal Area

Section .0800
Coastal Water Quality Policies

• DCM should take the lead role in coordinating the management of coastal resources with other divisions and commissions, i.e. DWQ and the EMC and DMF and the Marine Fisheries Commission (MFC).

• DCM should obtain review authority over certain MFC decisions. Conversely, DMF should have review authority over decisions that affect primary nursery areas. DCM should work with DMF, the MFC, DWQ and the EMC to address the following fisheries management issues:

— Equal consideration should be given to impacts on invertebrates and noncommercial/recreational fishes when establishing regulations.

— A multispecies approach should be used in fisheries management.

— The potential effects on fisheries of natural hormones and those introduced through animal operations should be evaluated and monitored. Proximity of animal operations, animal processing plants and certain aquaculture facilities, and the potential impacts of runoff from these facilities to important fish habitats should be investigated.

— The effects of pathogen stimulation to fish from sources such as sewage and urban runoff should be evaluated. Known "hot spots" should be monitored during appropriate seasons. Proximity of sewage, urban runoff, septic systems and other sources to important fish habitats and the associated impacts should be investigated.

— Fish kills should be closely monitored and evaluated as a major sign of stress and adverse impacts to fisheries.

— Chronic sublethal impacts of pollutants discharged to primary and secondary fish nursery areas should be thoroughly evaluated before such discharges are permitted. Management decisions should be based on the outcome of that research.

• DCM should seek review from DMF for projects such as dredging for beach nourishment, mitigation for bridge construction and associated SAV damage, and other activities that will damage fish or aquatic habitat.

Phase II: Expanding Coastal Resource Protection

As the Environmental Systems Team and the Coastal Resource Teams have identified, many different human activities and land uses within our coastal watershed contribute to the degradation of coastal resources. In order to fully protect coastal resources from these activities, our management of coastal waters and coastal resource quality must expand beyond the geographic area and the activities currently regulated by our coastal management program through CAMA, the AEC structure and other programs. Implementation of the 6217 program would be a start in the right direction (U.S. EPA 1993).

Therefore, the CAMA permitting process should expand beyond the AECs to all areas influencing the quality of our coastal resources.

N.C.G.S. 113A-103
Definitions

Consider revising the definition of "Coastal area" and "Coastal sound" to include the entire coastal watershed or at least those portions that can be identified as significantly influencing the condition of estuarine resources. In addition, upstream "noncoastal areas" contain important spawning grounds for estuarine-dependent anadromous fish; a revised definition could help provide some measure of protection for this critical riverine habitat.

Consider revising the definition of development to include activities such as road maintenance; raising of livestock and poultry; and agriculture, forestry activities and other land-altering practices.

N.C.G.S. 113A-115
Designation of Areas of Environmental Concern

(C) Ensure that AECs are reviewed biennially and encourage that new AECs be designated according to the process defined in Phase I under N.C.G.S. 113A-113.

15 NCAC 07H
State Guidelines for Areas of Environmental Concern

Section .0503
Natural and Cultural Resource Areas

New AECs should include anadromous fish spawning areas, freshwater riparian buffers and areas of exceptional aesthetic value. These AECs should be added to the list of Critical Habitat Areas.

Anadromous fish spawning areas should be established as an AEC and included in the definition of a Critical Habitat Area. The anadromous fish spawning areas should include the river segment used for spawning, the adjacent riparian area that provides shade to the water, and the upstream river and associated riparian area that has significant influence on water quality and water delivery to the spawning area. All development within these spawning areas should be subject to the Critical Habitat Area use standards in 15 NCAC 07H Sections .0205(d), .0206(d), .0208 and .0209(e)(f). In addition, the following use standards should apply specifically to anadromous fish spawning areas:

- Shoreline projects should be prohibited if they disrupt the riparian area, especially overhanging vegetation, to an extent that results in heating of water, reduction in dissolved oxygen or delivery of sediment to an extent that would suffocate or smother eggs or harm adult fish.
- Hydropower or other water use and discharge activities should not significantly disrupt water delivery. No holding of water followed by large releases that would disrupt spawning activities should occur.
- Reservoirs or hydropower facilities should be prohibited from discharging significant amounts of heated waters upstream of or directly to spawning areas. All reservoirs should include low drain systems designed to draw cooler bottom waters when needed. If bottom waters are anoxic, resulting downstream dissolved oxygen levels should be determined and oxygenation should be considered.
- Culverts, dams, logjams or other riparian cut-throughs that would result in exclusion of fish to spawning areas should not be permitted.

Current literature on riparian buffers should be reviewed to determine adequate buffer widths, design and maintenance.

- Development that is nonwater-dependent or that is known to cause water quality degradation should be restricted from buffer areas. Examples include livestock facilities, cropland, golf courses, timber harvesting, sewage treatment plants, septic systems, etc. (see diagrams in Appendix B to develop a more complete list).

N.C.G.S. 113A-118
Permit Required

The criteria that determine whether a project requires a CAMA Major Development Permit should be evaluated and revised. It has been determined that many other types of development besides those currently required to obtain a CAMA major development permit contribute directly, and on a cumulative basis, to resource degradation. This would make the CAMA Major Development Permit applicable to a greater diversity and number of projects and allow the impacts of each individual development project to be considered and assessed on a cumulative basis. An associated recommendation is to improve the CAMA permitting process.

N.C.G.S. 113A-120
Grant or Denial of Permits

An applicant's record for at least seven years prior to the application date should be considered in order to identify any previous violations.

N.C.G.S. 113A-124
Additional Powers and Duties

Fully utilize section (a)(1) in order to ensure that a sufficient amount of evidence has been made available for a balanced judgement to be made regarding development in an AEC.

15 NCAC 07H
State Guidelines for Areas of Environmental Concern

Section .0205
Coastal Wetlands

The following are general recommendations that should be considered for better protection of coastal wetlands.

- DCM should make every effort to protect coastal wetlands that serve as Critical Habitat Areas.
- Wetlands adjacent to fish nursery areas should receive special protection.
- DCM should identify, evaluate and map wetlands according to indigenous species habitat, water characteristics, tidal flows, soil type and existing land use similar to the current Advanced Identification (ADID) program.
- DCM should rank wetlands based on value factors, identify additional areas where Critical Habitats are located, and manage future development based on use standards developed for each resource.
- DCM should make significant efforts to restore, enhance and create coastal wetlands as stated in 15 NCAC 07M Section .0700 Mitigation Policy.
- DCM should further identify effective wetland mitigation techniques, determine appropriate ratios for mitigation (wetlands construction versus wetlands destroyed) and establish mandatory wetland mitigation efforts.
- DCM should set up a fund, using permit fees, to help defray the public costs of mitigation and monitoring for a period of at least 20 years to assess changes in species diversity, water level and water quality. Other innovative monetary programs should be investigated and considered.
- The permit applicant should be made aware of the costs associated with mitigation and be responsible for the financial burden associated with wetland mitigation.
- Nonregulatory programs such as land acquisition, tax credits, subsidies, transferable development rights and environmental education should be used to prevent wetland disturbances.

Section .0206
Estuarine Waters

The following recommendations should be considered for better protection of estuarine waters. Many of these proposed changes will require interagency coordination, especially with DWQ.

(d) Use Standards

- Identify acceptable and suitable land uses and ensure that development meets established surface water quality standards and identified carrying capacities for turbidity, TSS, salinity, DO, oxygen, toxins, pathogens and nutrients both individually and cumulatively. Water quality standards should be developed based on the location and type of individual resources found within the estuarine water; the type, extent and density of existing development, and the type, extent and density of future development.
- The classification "Outstanding Resource Waters" should be revised to include waters that, with some level of restoration, may feasibly be classified as an ORW or that were formerly an ORW.
- Enhance and restore the quality of water bodies to their highest possible classification. Water quality standards should be based on the potential water quality classification for the water body, not on existing classifications. Efforts should be taken to identify degraded areas that may be restored to ORW or HQW status and take the appropriate mitigation efforts to restore these waters, based on technical and economic feasibility as provided in 15 NCAC 07M Section .0700 Mitigation Policy;
- Establish programs and increase incentives to better manage Critical Habitat Areas in private ownership;
- Quantify and establish cause-and-effect relationships between land-use activities and surface water quality;
- Establish a program for mandatory implementation of BMPs in highly degraded waters, based on resource value degradation;
- Coordinate with DWQ to monitor incidence of fish kills and diseases and evaluate them as indicators of system stress and water quality degradation. The monitoring system should include an emergency response program for off-hour kills so that the causative agents of kills can be more accurately evaluated at or near the time of death;
- Strengthen the use of biological indicators to determine hazardous levels of toxics. Biological indicators should include species representing the entire food web. Species should be exposed to samples of riverine and estuarine water and sediment and their survival observed. Salinity, dissolved oxygen, pH, pathogens and other factors should be examined simultaneously to determine if they are affecting survival. Changes in reproduction, growth and behavior and other impacts should also be monitored;

• Minimize the discharge of metals, pesticides and other toxic substances to the estuarine system.

Section .0209
Estuarine Shorelines

• If DCM's intended benefit of the estuarine shoreline AEC is to protect estuarine resource quality, then this needs to be clearly stated and development standards made more restrictive. Exclusion of certain activities and land uses from the estuarine shoreline should be considered. DCM should compile a list of activities and land uses that are to be excluded from the estuarine shoreline, including ones that are not water-dependent and are known to contribute to degradation of water quality and coastal resources.

• The parameters that currently define an estuarine shoreline should be evaluated and updated to ensure that they adequately encompass all activities that have a negative effect on estuarine resources or contribute cumulatively to estuarine resource degradation.

• The existing 75-foot estuarine shoreline setback and the 575-foot setback adjacent to HQW should be revised and increased to better address cumulative impacts of development currently falling outside of this boundary.

• DCM should allow for a mutual exchange of information with the permit applicant during the preproject planning stages of development. This should help DCM determine possible project shortcomings and potential changes in an attempt to minimize permit processing time and costs. In addition, this will provide an avenue for discussion between applicants and DCM and allow a more efficient decision regarding a CAMA development permit within the estuarine shoreline AEC.

The following recommendations provide a more comprehensive approach to better manage development and reduce cumulative impacts of development within the estuarine shoreline AEC. These recommendations are tailored to specific land uses or human activities that the resource teams identified as causes of coastal resource degradation. CAMA permitting should expand to address all the following activities and land uses.

Residential Development and Commercial Development

• DCM should establish internal specification standards for evaluating plans/activities prior to permit approval. Permit applicants should be made aware of these standards and what must be undertaken to minimize resource impacts and should be required to adequately address the standards as a condition of permit approval.

The following criteria could be included in the development of evaluation standards:

— requirement of temporary and permanent remedial measures for addressing sedimentation and runoff,

— standards for effective minimum buffer widths, filter strips, setback requirements, constructed wetlands, on-site containment and filtration devices, and impervious/permeable paving ratios based on pollutant removal and hydraulic containment capabilities and efficiency;

— development-density standards for different land uses based on proximity to surface water, groundwater, nearby estuarine resources, open space preservation and existing development;

— increased flexibility regarding stormwater treatment efficiency and reuse, design specifications, and temporary stormwater detention devices.

• Require that minimum subdivision development plans be at an accurate, appropriate, project-specific scale and should include standards that address the following:

— topographic detail relative to project size;

— existing site conditions and critical area mapping;

— clearing limits (especially near wetlands and riparian buffers);

— activities scheduling;

— material and equipment staging/storage areas;

— temporary and permanent stabilization/erosion-control methods based on hydraulic/sediment calculations, not existing sedimentation and erosion standards;

— maintenance/removal procedures for BMPs and other devices;

— extensive monitoring, maintenance and performance reviews.

• Encourage local governments to adopt ordinances to minimize impervious surface. Examples include:

— narrower road widths;

— cluster development to reduce road lengths, and maintain open spaces adjacent to surface waters as treatment areas;

— restrictions on layout of subdivision cul-de-sacs and roadways to reduce impervious surface and encourage infiltration of stormwater;

— use of pervious materials for

driveways;

— restrictions on the number of parking spaces per square foot of commercial development to match average daily use, not potential maximum, and requirement that all overflow parking be constructed using pervious materials.

• Improve statewide databases on vegetation, hydrology, soils and topography and make the information available to all sectors to support plan development.

• Provide funding to support educational programs about the impacts of development on estuarine resources.

• Provide state training and certification for DCM field representatives, local permitting officers, the Land Quality Section of DEM, developers, contractors, silviculturists and farmers on the use of BMPs and methods of controlling sedimentation and erosion.

• Require preconstruction meetings between permit applicants and local permit officers or DCM field representatives.

• Increase financial incentives for project compliance:

— Establish plan and site review fees.

— Provide tax credit for compliance.

— Increase fines for noncompliance.

— Allow temporary work stoppages without court orders based on noncompliance.

— Require proof of financial viability for covered activity.

• Encourage the use of innovative approaches to treating stormwater runoff that combine a variety of techniques such as vegetated filters, wet and dry detention ponds, constructed wetlands and infiltration devices.

• Require all new developments to utilize on-site stormwater controls.

• Require local governments to adopt ordinances and zoning to maintain freshwater riparian and estuarine shorelines. Develop guidelines for maintaining these buffers and educate landowners on the importance of the buffer, its appropriate uses and effective maintenance. Post signs to indicate the extent and location of all buffers.

Construction, Road-Building, Forestry Practices and Mining

• Require all current land-disturbing activities to be included in land-use management plans filed by landowners or managers that indicate how the land is being used and managed and if it may be cleared or converted to a different land use in the future.

• Review construction plans to determine the effectiveness of temporary control measures to be used during project activity and permanent management measures. For example, will a wet detention pond suffice for the lifetime of the project?

• Provide funding to perform plan reviews, permitting and site inspection at the local level with regulatory consistency and technical assistance provided by the state.

• Develop an educational program to inform all age groups about the dangers of sedimentation and the importance of erosion control. Establish a number for citizens to report violators (i.e. sites with improper or malfunctioning controls or no controls at all) and an emergency response program with adequate personnel and funding.

Golf Courses

• Quantify the localized impacts, including the effects on the aquatic community of golf course development and management on coastal resources and water quality.

• Establish effective BMPs to increase the environmental compatibility of golf courses with coastal resources and water quality.

• Develop an incentive program to accelerate adoption and implementation of effective BMPs on golf courses.

• Create user awareness of the environmental costs of intensive golf course management and maintenance.

• Ensure the thorough and proper siting of golf courses by withholding permits based on poor course development that is inconsistent with estuarine water quality management objectives.

• Encourage the development of golf courses in areas that are already disrupted or degraded, where the golf course installation and proper management could serve to improve conditions of surrounding waters rather than degrade pristine areas.

• Encourage the use of treated wastewater including innovations for water reuse for golf course irrigation, especially for developments that pair a golf course with residential housing and that have treatment works designed for domestic wastewater only.

Municipal Wastewater Treatment Plants

• Establish nitrogen-reduction targets for various river basins and subbasins and mechanisms to see that they are achieved.

• Implement human population density control planning. Comprehensive, long-term projections of the relationship between human population density and estuarine water quality on a basinwide, subbasin and a localized scale will help local governments prepare for growth.

• Maintain and expand the phosphate detergent ban. The phosphate detergent ban should be maintained for domestic detergents and expanded to industrial detergents. This strategy is more effective in freshwater systems where phosphorus is limiting and may not be as effective in nitrogen-limiting estuarine waters. However, both nutrients should be controlled.

• Enhance industrial pretreatment. It is more economical and effective for industry to minimize the quantity of toxic substances resulting from an industrial process than to treat it at a municipal wastewater treatment plant. Require industries to phase out use of major toxic substances that harm sensitive coastal areas.

• Mandate programs that require water conservation and reuse. Reducing the overall quantity of water used reduces the amount ultimately needing treatment and reduces the need for new water supplies. Thus, conservation reduces the need to divert ecologically important freshwater flows from estuaries.

• Expand household hazardous waste reduction. Education and outreach to households can reduce the quantity of hazardous chemicals used and improve disposal practices. Improve frequency and extent of household hazardous waste collection at the county level.

• Research and implement nutrient trading. A system of buying and selling of pollutant discharge allowance quantities among point and nonpoint source polluters can be economical and reduce current overall pollutant loading levels. Limits should be set to ensure that the trading process begins in the near future.

• Rely on strong standards and permits. Compliance measures would strengthen wastewater treatment by prescribing exactly how much of a pollutant a discharger is allowed to release. Standards should be developed by river segment or subregion for nitrogen, phosphorus, enterococci and other variables.

• Carefully examine alternatives such as effluent, user and product charges; tax differentiation, and subsidies. Use financial incentives and penalties to manage the amount of pollutants being discharged. Develop a strong integrated program with benefits that are returned to the regulatory program.

• Reuse and recycle treated sewage wastewater and apply sludge over land. Reusing and recycling are potential ways to minimize disposal requirements and reduce treatment costs.

• Increase the efficiency of municipal treatment plants in removing nutrients. Better removal technologies can reduce the amount of nutrients being discharged into the estuarine environment. Such technologies should be mandatory in Nutrient Sensitive Waters and should include nitrate as well as ammonia and phosphorus removal.

• Research and develop natural wastewater systems and constructed wetland treatment systems. Copying and utilizing the pollutant removal mechanisms of existing natural systems may prove both effective and economical. Artificial systems should not, however, be developed to replace natural wetlands that would be lost through increased development.

• Base treatment requirements on environmental conditions. The degree of treatment required of a discharger would be dependent upon the actual environmental status of the receiving water body and associated parameters. For example, Nutrient Sensitive Waters should be managed with effective, enforceable mechanisms to reduce both total inorganic nitrogen and total phosphorus loadings.

• Develop and implement better ways to identify water pollution. Accurate, inexpensive and effective ways to identify bacterial, virus, and pathogenic water contamination are greatly needed. For example, other states have adopted enterococci as a standard. Potential usefulness of fecal coliphages should also be considered.

• Choose appropriate sites for wastewater treatment plants. Place new treatment plants in areas that can best handle the amount of effluent that the plant will produce.

Pulp and Paper Wastes

• Eliminate chlorine bleaching procedures. Expand the use of oxygen or ozone bleaching or eliminate bleaching altogether.

• Promote paper recycling, reducing the need for new sources of paper.

• Improve treatment technologies to

reduce nitrogen and phosphorus discharge amounts. Better removal technologies can reduce the amount of nutrients being discharged into the estuarine environment.

Aquaculture

• Continue with the existing DEM permitting requirement that addresses site alterations and pond construction.

• Pond review should also consider impacts to downstream habitats such as oyster reefs and primary nursery areas. If release of eutrophic or turbid water from the facility will negatively impact the habitat, pond location and/or operation should be modified. Deny permits if impacts are unavoidable.

Seafood Processing

• Continue with the existing NPDES and stormwater discharge permitting process managed by DWQ.

• Provide DCM with all permit information obtained by DWQ.

On-Site Waste Treatment/Septic Systems

• Accelerate research, adoption and implementation of alternative on-site waste treatment BMPs. Evaluate the effectiveness of BMPs using the expertise of aquatic ecologists as well as engineers and other technical experts.

• Establish wide-scale demonstrations and evaluation for site specific on-site waste treatment alternatives.

• Increase awareness of the need for homeowners to conduct routine septic system maintenance.

• Expand the jurisdiction of waste management entities to provide routine inspection of all types of septic systems.

• Implement a policy requiring low-flow systems in critical areas.

Agriculture and Forestry

The following activities should be used to encourage those engaged in agriculture and forestry activities to take an active role in minimizing estuarine resource degradation.

• Determine individuals not currently participating in Agriculture Cost Share Program and expand incentives for voluntary BMP implementation.

• Increase funding to provide technical assistance for BMP implementation.

• Correlate and rank BMP effectiveness associated with specific land uses and resources in North Carolina's coastal region or watersheds.

• Tailor incentive programs to target BMP implementation based on documented effectiveness for given land use and identified water quality problems.

• Adopt and extend the Farmstead Assessment System to facilitate a "whole" farm environmental assessment on water quality.

• Expand educational awareness of the potential risks to coastal water quality through implementation of an environmental assessment program on all farms in the identified coastal region. Target farm trade shows, banks and fertilizer companies for expanded outreach and education regarding coastal water quality issues.

• Increase incentives for producers to adopt production practices that reduce applications of chemicals.

• Strengthen compliance and enforcement to detect and correct water quality violations resulting from nonpoint source pollution.

Section .0500
Natural and Cultural Resource Areas

This AEC category should be better utilized to promote the protection of estuarine resources.

15 NCAC 07K
Activities in Areas of Environmental Concern That Do Not Require A Coastal Area Management Act Permit

Section .0208
Single Family Residences Exempted

Ensure that all single family residences that are exempted from the CAMA permit requirement are consistent with the criteria for the estuarine and ORW shoreline AECs proposed by this report.

15 NCAC 07M
General Policy Guidelines for the Coastal Area

Section .0700
Mitigation Policies

• DCM should work with DWQ to restore coastal waters to their assigned use classifications and to restore associated resources to their appropriate function. In areas suffering from water quality problems identified by the Water Quality Team (i.e. nuisance algae blooms, fish kills, etc.), the charts in Appendix B should be used to determine the human activities and land uses that are causing the problem. The geographic area over which the activities are occurring should then be determined. Management measures identified by the EST should be implemented to reduce the contribution from each land use or human activity within the appropriate geographic area.

• DCM should develop a retrofitting program for developed areas to enhance existing runoff control structures or conveyance systems in order to improve estuarine water quality. Regional stormwater facilities should be examined as a potential mechanism to mitigate the impacts from existing development.

• DCM should identify priority wetlands for restoration. These should include wetlands near critical habitat AECs, ORWs, HQWs or other important coastal resources, wetlands that would be most easily restored, and wetlands that are considered high value because of filtering capacity or habitat for endangered or threatened species. For example, high priority should be given to restoration of freshwater riparian wetlands along sloped riverine shorelines because of their water cleansing ability and to brackish and saltwater marshes near SAV because of their ability to protect the grass beds.

• DCM should work with DMF to increase available fisheries habitat through mitigation. Priority should be given to restoration of access to historical anadromous fish spawning areas.

• Mitigation projects for SAV beds and oyster reefs should consider the context of the habitat and its functions. Adequate shallow sand or sand/mud area and flow currents must be maintained for both oyster reefs and SAV beds.

• Migratory and access routes for fish must be maintained in all preservation, restoration and creation efforts.

Section .0800
Coastal Water Quality Policies

This section may provide the foundation for extending coastal area management beyond the existing coastal boundary and allow for the implementation of management actions and recommendations outside of the existing defined coastal area. ***This management should apply to the entire coastal watershed and all land uses and human activities contributing to degradation of coastal resources. In particular, the land-based recommendations this report proposes for the estuarine shoreline should be applied to the entire coastal watershed.***

• DCM should use this section to improve estuarine resource quality by taking a basinwide approach to estuarine resource management through the implementation of BMPs and other recommendations described in this section of the report. This approach should include reductions to point, nonpoint and atmospheric sources of pollutants.

• Use this section to evaluate the feasibility of using freshwater riparian buffers along identified critical habitat areas.

Phase III: Sustainability and Land/Water Use Planning

Sustainability

In order to adequately address the cumulative impacts of growth and development on our coastal resources, North Carolina's coastal management program must evaluate the sustainability of the coast on a watershed, subbasin and critical habitat area basis. In addition to the recommendations presented in Phases I and II, which suggest specific amendments to the existing CAMA management structure, Phase III outlines a procedure for determining the threshold of development that each specific coastal environment can tolerate. It also outlines steps for implementing the regulations to ensure this threshold is not exceeded.

In order to determine the sustainable level of development that can occur along the coast without impacting identified Critical Habitats, an Area of Influence for each habitat type must first be determined. The Area of Influence is the region immediately surrounding a Critical Habitat in which existing or proposed development would directly or cumulatively impact the habitat. DCM should initiate a study to identify the development variables that determine Areas of Influence and examine the relationship between critical habitat function and these development variables such as the percentage of impervious surface, area of land disturbance, septic tank density, buffer strip width, human population density and animal production density.

This evaluation should consider the current condition of North Carolina's Critical Habitats based on the existing level of development. Measures of critical habitat function could include closure of shellfish beds to harvesting or other losses of important shellfish community function(s), health of seagrass beds, and species utilization of forage, nursery or spawning areas. The results of this study should be used to set limitations on the amount and type of new development, in terms of identified variables, that can occur within the Area of Influence while maintaining the quality and functions of the Critical Habitats. If the area of influence for the critical habitat is found to extend beyond the current 75-foot estuarine shoreline boundary, then: the boundary may need to be expanded near certain critical habitats; an AEC subcategory may need to be established to identify and regulate the development that is outside the existing geographic coverage of the AEC structure, but is influencing the condition of the critical habitat; or a new AEC category may need to be established to provide special use standards for the habitat and its associated area of influence. Critical habitat and area of influence delineations and their sustainable development levels would be identified by and maintained through county land-use plans.

Sustainability evaluations should also be applied to protect coastal water quality on a watershed or subbasin level and, as needed, on a smaller scale to protect Outstanding Resource Waters from the cumulative impacts of development. Measures of water quality function should include frequency and occurrence of fish kills, algae blooms, contamination of water and sediment above current acceptable standards by metals or toxicants and accelerated levels of pathogens of known importance such as bacteria and toxic algae.

The implementation of county land-use plans must first be strengthened to incorporate the concepts of sustainability and protection of coastal water and Critical Habitat quality into county land-use planning. Currently, many counties complete land-use plans in order to comply with CAMA regulations but never utilize these plans to guide growth and development. Consequently, many of these plans are falling short of the goals and objectives set forth in 15 NCAC 07B Land Use Planning Guidelines. Technical assistance and training should be provided to counties developing their land-use plans.

Land-Use Planning

Land- and water-use planning must be better utilized to protect coastal wetlands, critical habitats, freshwater riparian areas, estuarine shorelines, estuarine waters, other existing AECs and other important coastal resources. As pointed out by the EST, planning can incorporate local needs and values in decisions that also protect important natural and cultural areas. Ideally, planning allows local policymakers to be oriented toward the future, rather than reactive and crisis-oriented.

Planning can be used to mitigate cumulative impacts. However, to do so adequately, plans must be interjurisdictional, include both land and water areas, and be enforceable. Ideally, the Coastal Resources Commission and the Division of Coastal Management should require that plans be extended beyond their current land-based focus to include water areas within each county. The commission and the division should then review the existing planning guidelines in 15 NCAC 7B Section .0200 to determine if they provide a development blueprint that adequately protects critical habitats and areas of influence. The 1990 Albemarle-Pamlico Estuarine Study report entitled North Carolina's Estuaries: A Pilot Study for Managing Multiple Use in the State's Public Trust Waters (Clark 1990) contains a model CAMA land- and water-use plan that could provide guidance.

Plans from different counties or municipalities that encompass the same watershed or river basin should be coordinated. The CRC and DCM should require that local governments work together through the planning process to protect critical habitats and the associated areas of influence. This requirement should be reflected in the CRC's planning guidelines.

CAMA should be amended to require that all local ordinances be consistent with approved plans. Currently, ordinances must be consistent with plans only if they affect an area of environmental concern. Since AECs encompass only about three percent of the land area of the 20 coastal counties, this is a substantial weakness that inhibits the implementation and enforcement of plans.

This type of land use planning should eventually extend beyond the existing 20 coastal counties and include all land areas.

Notes:

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Appendix A

UTILIZING COASTAL RESOURCE QUALITY TO ASSESS THE CAMA AEC MANAGEMENT STRUCTURE

WATER QUALITY TEAM

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Water Quality

For the purposes of this study, "good" water quality for coastal North Carolina is defined as the absence of six perceived problems:

I. fish kills and disease
II. nuisance algal blooms
III. shellfish contamination, disease, kills and closure of shellfish beds
IV. reductions in fish stocks
V. nursery habitat reduction
VI. human health hazards.

Although it is recognized that these problems may result from more than poor or degraded water quality alone, this summary focuses only on the aspects of water quality that contribute to the six problems. Other reasons for these problems, such as overfishing and bycatch, which expedite the reduction in fish populations, will be addressed separately by the fish and shellfish teams.

Following is an outline of the six specific water quality problems, the conditions that cause them, and the natural and human-initiated factors that contribute to these conditions. Many of the water quality conditions and their contributing factors are interrelated, and some of these interrelations are discussed. However, the natural and human-initiated factors are not discussed in great detail; they are merely listed to provide the Environmental Systems Team with some insight as to what activities should be included when developing a management strategy to prevent coastal resource degradation due to the cumulative impacts of development.

PROBLEM AREA I: FISH KILLS AND DISEASE

Situation

Fish kills and diseases are extremely important for several reasons and must be addressed within the framework of coastal resource management. Four important factors and considerations associated with fish kills and disease include: (1) the impacts on the biomass of the stock may be great; (2) fish disease and kills are not aesthetically pleasing; (3) there is a potential relationship between aquatic animal health and human health; and (4) fish health may be an indicator of general ecosystem health (Copeland and Steel 1991).

(1) Fish diseases and fish kills, coupled with the continued harvest of a species, may significantly reduce the stock of that species to a point where future stocks may be compromised and unable to rebound to adequate or sustainable levels.

(2) The visible impacts of fish disease and fish kills can decrease public demand for fish, limit the geographical extent from which fish can be harvested, and lead to the implementation of reactionary and potentially inappropriate management actions that fail to address the inherent complexity of the problem. A poor public perception regarding fish health and poor water quality will ultimately result in economic problems for both the commercial and recreational fishing industry (Perry 1987).

(3) Fish exposed to poor water quality, contaminants and stress often respond similarly to mammals and develop similar problems. In addition, human consumption of diseased fish may pose a potential risk to human health since the pathogens that affect the fish may also affect humans as well (Sindermann 1983).

(4) Fish diseases and fish kills may be an indicator of suboptimal environmental conditions. Although studies have shown that there may be a correlation between general ecosystem health and fish health, a direct cause-and-effect relationship has not yet been established (Copeland and Steel 1991).

Although the cumulative effects of disease on populations of aquatic organisms are not well understood, the potential for considerable damage exists (Copeland and Steel 1991). Because biological parameters associated with environmental quality vary both temporally and spatially in nature, the presence of a fish disease may not be readily known until the disease manifests itself in the form of a massive fish kill. For this reason, fish kills have historically been used as an indicator of fish disease (Copeland and Steel 1991).

Even though a massive fish kill is an acute phenomenon, it is most probably the result of disease and infection stimulated by a relatively slower, complex and chronic deterioration in water quality (Wedemeyer et al. 1984; Green 1984; Stewart 1987). Unfortunately, the signs of water quality degradation are often difficult to detect since any associated problems may be relatively small and considered unimportant. Often, a serious decrease in water quality is not realized until the devastating consequences, such as a massive fish kill, become apparent.

The Albemarle-Pamlico Estuarine Study has qualified the problems of fish kills and disease in the Albemarle-Pamlico estuarine system. In regard to fish kills, the Status and Trends Report of the Albemarle-Pamlico Estuarine Study states:

"Another major environmental concern of the fishing industry and fishery managers is the increasing occurrence of fish and crab kills in the Albemarle-Pamlico estuarine system, especially in the Tar-Pamlico River. A total of 87 fish and crab kills were reported in the Tar-Pamlico River between 1966 and 1984. From 1985 to 1987 a total of 31 fish and crab kills were documented by the N.C. Division of Environmental Management (DEM) in the Tar-Pamlico. Most of the documented kills have been attributed to hypoxia caused by algal blooms or salinity stratification and have occurred during warmer months in localized areas." (Copeland and Steel 1991)

In regard to fish disease, APES concluded:

"During the 1970s, large numbers of freshwater finfish species in the western portions of Albemarle Sound were affected by red sore disease. Approximately 50 percent of all commercially harvested finfish were observed with red sore disease during peak occurrences. While red sore disease subsided in Albemarle Sound in the 1980s, a multitude of ulcer-diseases has occurred principally in the Pamlico River, as well as in other areas. Most of the commercially important estuarine fish species utilizing the Pamlico River have been observed with lesions. The most prevalent disease is ulcerative mycosis, a fungal infection primarily affecting Atlantic menhaden. As many as 80-100 percent of the Atlantic menhaden in random cast net samples have had ulcerative mycosis. And more recently, an aggressive shell disease has been noted on blue crabs in the Pamlico River." (Copeland and Steel 1991)

Between 1980 and 1989, 153 fish kills involving approximately 260,000 fish were documented in North Carolina (NOAA 1991). Others are likely to have occurred, since North Carolina's fish kill records were recognized as the most incomplete among the Southeast United States (errata for NOAA 1991; Burkholder et al. 1995).

Causes of Fish Kills and Disease

The three main causes of fish kills and disease in North Carolina's estuaries have been identified as (A) oxygen deficit, (B) the presence of toxicants in the sediment and water and (C) pathogens. These three causes, and the natural and anthropogenic factors that contribute to each cause, are described below.

A. Oxygen Deficit (Hypoxia/Anoxia)

Hypoxia occurs when dissolved oxygen levels are very low, whereas anoxia is the complete lack of oxygen. Dissolved oxygen is essential to the respiratory metabolism of most aquatic organisms, which will die without it. Before there can be serious anoxia or hypoxia (especially in the Pamlico Sound), however, there must first be stratification — high levels of dissolved oxygen near the surface decreasing to much lower levels near the bottom.

Stratification, a natural occurrence in North Carolina's coastal sounds and estuaries, results from salinity differences that contribute to layering; dense saline waters become trapped beneath lighter fresh water. Stratification is most common in the upper reaches of the estuaries during periods of high runoff. Pronounced stratification usually lasts for two to three days and is ended by mixing of the water column due to winds and storms. Bottom waters, however, do not turn anoxic or hypoxic with every stratification event because mixing occurs before complete oxygen depletion takes place. In addition, anoxia and hypoxia are not common during the winter because lower temperatures slow down the production and decomposition of phytoplankton. Low oxygen levels usually do not occur in the bottom of the estuary when temperatures are lower than about 20 degrees Celsius (Copeland and Steel 1991).

Twenty years of sampling of the Pamlico River estuarine system indicates that mixing events naturally occur about every five to seven days (Stanley 1992). Trend analysis over this period shows that although the frequency and duration of stratification events have not changed, human impacts have caused an imbalance between oxygen consumption and oxygen production within estuarine waters. This is because oxygen-demanding wastes and dead algae and organic matter settle to the bottom where they consume oxygen through respiration and decomposition. As a result, increased loadings of oxygen-demanding waste have increased the rate of oxygen depletion in estuarine waters during stratification events. Even though the frequency of stratification events has not increased, the frequency of oxygen depletion during stratification has.

Since the rate of oxygen depletion has increased, the frequency of occurrence of anoxia and hypoxia during stratification events has also increased, thus, as Stanley says, "forcing the estuary to hold its breath longer and more often."

Contributing Factors:

1. Stratification of the water column
   a. salinity
   b. temperature
   c. circulation/wind (weather)
   d. increased river flow
      i. urban development — commercial and residential development and industrial sites
      ii. hydromodification — i.e. ditching and draining
      iii. amount of rainfall/runoff
2. Loading of oxygen-demanding organic material
   a. pulp mills
   b. wastewater treatment plants
   c. animal facilities
   d. marinas
   e. boat and barge usage
   f. seafood processing
   g. forestry operations
   h. septic systems
3. Internal decay of algae, aquatic vegetation and other organic material that consumes oxygen. Often a cycle of nutrient loading results in algal blooms that consume oxygen when they decay after dying. See Problem Area II: Nuisance Algal Blooms for information about the causes of, and contributing factors to, algae blooms

B. Presence of Toxicants in the Water and Sediment

Heavy metals and other trace elements are normal constituents of most ecosystems. However, natural concentrations are often supplemented by the activities of man (Riggs 1993). The fate of toxins and metals that enter the estuarine system depends on many factors, including physical and chemical environmental conditions, the form and manner in which an element is incorporated into the system, and the specific activities and characteristics of the aquatic organisms found within the estuarine system. As a result of contamination by toxic pollutants such as heavy metals, pesticides, PCBs and dioxin, aquatic life functions may be lost. These losses can be traced to disrupted communities, higher incidence of fish disease and changes to population dynamics such as reduced fecundity, reduced survival of juvenile stages, and fish kills.

Most toxicants are considered conservative substances and are not readily assimilated into the estuarine system. Rather, they tend to accumulate in the finer sediments of the estuary and can result in extremely high concentrations that can be potentially harm fish (Cunningham 1992). Since toxicants can accumulate over time, the continued loadings of toxins and metals to coastal waters are as important as the current extent of toxicant contamination.

The presence and degree of toxicants in the estuarine system are apparent because of acute effects on living aquatic organisms. An extremely important consequence of toxic loadings on aquatic organisms is bioaccumulation. Bioaccumulation is a process by which living organisms slowly ingest and store small amounts of certain synthetic chemicals, which ultimately results in very high concentrations over time. These toxic chemicals become further concentrated in organisms as they, in turn, consume other contaminated organisms. The phenomenon of increased toxic concentrations at each level in the food chain is known as biomagnification. At the highest levels, organisms may accumulate concentrations of a toxic chemical high enough to cause deformities or death or impair their ability to reproduce (EPA 1994). Of particular concern in estuarine ecosystems is the presence and bioaccumulation of mercury, which is a proven fetal and neurological toxicant in humans and animals. Severe or prolonged exposures can affect the viability of offspring and can affect neurological function and behavior in adults (Cunningham 1992).

To identify the extent of toxic contamination in fish, the North Carolina Division of Environmental Management (now called the Division of Water Quality) conducted fish tissue sampling at 41 locations in the APES region in 1989. Seven hundred forty-three samples were analyzed for metals, and 98 samples were analyzed for synthetic organic chemicals. Results showed that only six of the 420 fish fillets analyzed for mercury contained concentrations at or above the FDA action level. However, four of the six came from the Chowan River at Riddicksville (DEM 1991). High percentages of detectable lead concentrations were found at four sampling locations primarily around the Pamlico River estuary (DEM 1991). Researchers looked for the presence of 13 pesticides; nine were detected but none in concentrations at or above the FDA action levels. Results show that the primary toxicants of concern within the Albemarle-Pamlico Estuarine system are mercury and dioxin (Cunningham 1992).

In North Carolina, if fish have toxicant levels that are above approved FDA action levels, consumption advisories are issued. This is a common practice in other states such as Florida and Michigan (Cunningham 1992). In addition to fish consumption advisories, the state of North Carolina also protects humans from consuming contaminated shellfish. Fecal coliform tests are used as an indicator of the presence of other bacteria and viruses in the water, and shellfish harvesting is prohibited when levels exceed the approved minimum standard. Shellfish harvesting is also prohibited within a prescribed distance from marinas (Waite et al. 1994).

The North Carolina Division of Marine Fisheries considers toxicant contamination to be "the most complex and potentially devastating threat to coastal waters" (DMF 1991). NOAA's National Status and Trends Program, however, indicated no "high" concentrations of monitored metals and toxics in tissues of bottom-feeding fish and shellfish or in sediment samples at five North Carolina locations (NOAA 1990). Even though contamination of estuarine sediment and water by toxicants is not yet a widespread problem worthy of national ranking, "hot spots" containing elevated levels of metals have been identified in the estuarine region of North Carolina through research supported by the Albemarle-Pamlico Estuarine Study (Cunningham 1992; Riggs 1989, 1990, 1992).

Currently, there is not enough information available to adequately determine necessary management measures for toxicants. Accordingly, this problem area needs assessment. In particular, biological indicators should be used to determine hazardous levels of toxins instead of just considering concentrations in the sediment, water column and fish tissue. Biological indicators should include fish, zooplankton and species representing the entire food web. At the University of Maryland's Wye Research and Education Center, scientists observe what happens to selected species when they are exposed to samples of water and sediment taken from specific Wye River sites rather than merely testing the water for the presence of chemicals. Salinity, dissolved oxygen, pH and other factors are also examined to determine if they are affecting survival. Changes in reproduction, growth and behavior and other impacts are also monitored (Blankenship 1994).

However, the coastal system is complicated. Many biological trends correlate to a number of chemical contaminants and physical conditions with no one factor clearly being the cause. In many of these cases, measurements of a suite of potential chemicals in the water column may be the only reliable method to identify the problems. Biological indicators such as fish populations, fish diseases and the health and presence of seagrass species can be good indicators for targeting areas of concern (for pesticides, see Madhun and Freed 1990). Further investigation can often identify the source(s) of the problems. However, these indicators often identify the problem at a stage at which it's difficult or impossible to biologically reverse the problem.

Another approach is to monitor a few selected chemicals. For example, the presence of nitrate-nitrogen can often signal potential problems in groundwater systems (for example, see Fletcher 1991). If high concentrations are found, then further investigation is done. The potential contaminants are identified based on land use, and chemical analyses are done to measure the presence of these contaminants. In agriculture, many production systems can be screened for potential environmental effects by using computer simulation models (for example, see Geter et al. 1992).

Water Contamination

According to APES, in 1989-1990 in the APES region under average flow conditions, 12 dischargers were predicted to have the potential to cause water quality exceedances, with municipal facilities accounting for 79 percent of these dischargers. In the system, 24 freshwater and 6 estuarine stations had ambient pollutant concentrations in the water column that exceeded state and EPA standards. Industrial wastes treated at municipal facilities were the most likely sources of discharged toxicants (Cunningham 1992).

Sediment Contamination

In 1989-1990, 51 sites within the APES region had sediment contamination levels above the median effects range (ER-M) values derived by NOAA. ER-M values represent the concentration above which toxic effects are frequently or always observed among most species. Sites where ER-M exceedances were detected represent areas where sediment contamination is most likely to produce toxic effects in aquatic organisms (Cunningham 1992).

Toxicity enrichment of sediment in the Pamlico River Estuary tended to be site-specific, with most sites having greater metal concentrations in surface samples than in deeper samples, indicating recent anthropogenic contamination (Riggs 1989). In the Neuse River estuary, all sites exceeding the ER-M levels were associated with known point source dischargers (Riggs 1990).

Of metals, chromium, zinc, copper and lead generally account for the highest loading rates in the APES region. However, fluoride is the largest single source of a toxicant entering the system (Cunningham 1992).

There is concern about further contamination of North Carolina's coastal waters by metals, pesticides and other toxic substances, especially from point sources such as wastewater treatment plants, marinas, plating facilities and military installations (Riggs 1989). Stormwater and nonpoint source runoff are also primary vehicles for toxicant loadings into coastal and estuarine waters.

Contributing Factors:

1. Point source discharges
   a. industrial wastewater discharge
   b. wastewater treatment plants
   c. pulp mills
2. Nonpoint source/stormwater discharges
   a. residential development
   b. commercial development
   c. industrial sites
   d. cropland
   e. mining areas
   f. forestry operations
   g. marinas
   h. golf courses
   i. boats and barges
   j. septic systems
   k. construction
   l. road-building
3. Atmospheric deposition
   a. industrial air discharges
   b. automobiles
4. Dredging — dredge spoil deposition/toxicant recycling

C. Pathogens (bacteria, viruses and fungi)

The presence of certain pathogens (bacteria, viruses and fungi) can directly cause fish kills. Other pathogens can weaken fish, making them more vulnerable to infection by other opportunistic bacteria, viruses, diseases and other naturally present mortality sources. The symbiotic relationships between bacteria and other pathogens is not clearly understood. However, significant evidence shows that environmental factors most likely influence the susceptibility of fish to pathogenic infection, thereby playing an important role in the development of fish diseases, especially in the Albemarle-Pamlico estuarine system. In fact, localized reduced immunocompetence in fish is evidence of an environmental effect, even when the specific infecting agent can not be identified (Stewart 1987).

Land-based pathogens or pathogens associated with human activities reach coastal waters by both point and nonpoint sources, especially wastewater treatment plants, failing or faulty septic systems and urban runoff (EPA 1991).

Toxic Dinoflagellate

A newly discovered toxic estuarine dinoflagellate has been identified within the Albemarle-Pamlico estuarine system and has been linked to approximately half of the major fish kills in the Neuse and Pamlico estuaries during 1991-1993. Formerly known as *Pfiesteria piscimorte*, it is now officially named *Pfiesteria piscicida* (Steidinger et al. 1996). It is lethal to all 18 species of native and exotic finfish and shellfish tested, with more species apparently succumbing in estuarine fish kills (Burkholder et al. 1995).

Apparently stimulated by fresh fish excreta and nutrients, *Pfiesteria piscicida* is lethal across broad temperature, salinity and light gradients, with sublethal long-term exposure causing damage to epidermal, neural, immune and reproductive systems. At least two-thirds of the reported fish kills related to the toxic algae have occurred in phosphate-enriched waters of the Pamlico estuary (Burkholder et al. 1995).

Contributing Factors:

1. High nutrients (especially phosphorus; also direct stimulation by dissolved nitrogen substances and by nitrate)
    - a. wastewater treatment plants
    - b. industrial wastewater discharges
    - c. cropland
    - d. animal facilities
    - e. industrial air discharges
    - f. residential development
    - g. commercial development
    - h. golf courses
    - i. forestry operations
    - j. marinas
    - k. septic tanks
    - l. atmospheric deposition

Ulcerative Mycosis

Ulcerative mycosis (UM) is caused by two pathogenic fungi, *Aphanomyces* and *Saprolegnia*. Evidence suggests that UM development may be associated with fluctuations in dissolved oxygen as well as with lower pH. Also, a degradation in water quality that causes fish stress makes the fish more susceptible to the pathogenic fungi. The strongest environmental factor correlated with UM is salinity, since UM primarily affects young fish in areas of low salinity during the months of May and June (Noga 1993).

Even without the manifestation of UM, the pathogenic fungi responsible for the disease are continuously present in the estuarine system. Therefore, it is assumed that some aspect of water quality or some change in environmental conditions affects the prevalence of UM and possibly all infectious diseases affecting fishery populations (Noga 1993).

It is uncertain which factors contribute to the appearance of UM and whether direct or indirect anthropogenic influences have any effect (Noga 1993). In the case of Atlantic menhaden, however, the two fungi that cause ulcerative mycosis seem to be able to penetrate the fish through the lesions inflicted by the toxic dinoflagellate, *Pfiesteria piscicida* (Burkholder et al. 1995).

Contributing Factors:

1. Toxic dinoflagellate
    - a. high phosphorus (see contributing factors under Toxic Dinoflagellate)
2. Environmental conditions that reduce the resistance of the host
    - a. temperature extremes (lower temperatures are more conducive to UM)
        - i. weather
        - ii. industrial wastewater discharges (coolant water)
    - b. low dissolved oxygen
        - i. external organic carbon loadings that consume oxygen. See Cause A. Oxygen Deficit, Contributing Factor 2 for sources of organic

material

ii. internal decay of algae, aquatic vegetation and other organic material that consumes oxygen. Often, a cycle of nutrient loading results in algal blooms that consume oxygen when they decay after dying. See Problem Area II Nuisance Algal Blooms for information about the causes of and contributing factors to algae blooms

c. rapid fluctuations in salinity

i. hydromodification

ii. weather

iii. increased impervious surface from urban development

d. low pH

i. acidic industrial wastewater discharges

ii. industrial air discharges

iii. automobiles

iv. chemical weathering of acidic sediments

3. Environmental conditions that are favorable for the fungi that cause ulcerative mycosis.

a. actual salinity of the water (between 4-8 parts per thousand is optimal for the growth of the fungi that causes UM) (Noga et al. 1993)

b. low pH is favorable to the growth of fungi causing UM (Noga et al. 1993)

i. acidic industrial wastewater discharges

c. seasonal climatic variations affecting the incidence of UM (not sure which specific factors, such as temperature or precipitation, are most directly related to UM). Occurrences of UM are most prevalent in spring and early summer; they usually decrease at the onset of winter.

PROBLEM AREA II: NUISANCE ALGAL BLOOMS

Situation

Nuisance algae blooms can consist of blue-green algae; dinoflagellates, including the North Carolina endemic species, *Pfiesteria piscicida*, as well as species that produce "red tide"; chrysophytes (e.g. some flagellates and the colony-forming organism *Phaeocystis*, an indicator of raw sewage); and even normally benign diatoms. All but the blue-greens are primarily estuarine or marine. Most algae are beneficial because they support the food chains of aquatic ecosystems. However, when they are overstimulated by nutrient enrichment, even the beneficial algae can form blooms that rob the water of oxygen during the night. Although relatively few algal species are directly toxic to fish and other aquatic life, these "rogue" species have been documented to cause fish kills in both freshwater (blue-greens) and estuarine/marine habitat (*Pfiesteria*). Other adverse effects associated with nuisance algal blooms are surface scums with undesirable odors, water discoloration or taste problems, and imbalances in the food chain. Food chain imbalances occur when desirable species of algae are overgrown by the bloom formers, leading to reduction in growth of desirable animals from zooplankton to fish (Lembi and Waaland 1987).

Many bloom species release toxins that have the potential to cause illness or death if ingested by humans or animals. Dermal exposure and inhalation of some toxins can also cause sickness and disease. Some toxins can cause fish and shellfish kills. In addition, consumption of fish or shellfish that have accumulated lethal levels of certain toxins can poison or kill humans and wildlife (Falconer 1993).

North Carolina's coast was declared a national disaster area as a result of the 1987 red tide. Approximately 50 percent of commercially harvested oyster areas and 95 to 98 percent of clam areas were closed, resulting in an estimated loss of $26 million (Burkholder 1993a). More frequent and intense algal bloom activity, particularly consisting of surface scum-forming nuisance blue-green algae, has occurred in both the Chowan and Neuse rivers (Paerl 1990).

The primary source of algae blooms is increased loadings of nutrients to coastal waters. Many toxic algae species are believed to have always been on our coast, while others are suspected as new arrivals, probably taxied in the ballast water of oceangoing ships (Culotta 1992).

Causes of Nuisance Algal Blooms

The main causes of nuisance algal blooms in North Carolina estuaries have been identified as (A) increased nutrient concentration, (B) nutrient recycling and (C) food chain disruptions. These three causes and the natural and anthropogenic factors that contribute to each are described below.

A. Increased Nutrient Concentrations

Nutrients such as nitrogen and phosphorus are essential to production in estuarine waters and are an essential component for the base of the aquatic food chain. Too many nutrients, however, can excessively increase productivity, sometimes resulting in algal blooms. Nutrients are discharged to coastal waters by point, nonpoint and atmospheric discharges. Certain activities and changes in landscape can also cause land-based nutrients to flush into coastal waters more rapidly. Discharges or land disturbances that result in increased loadings of organics and trace elements into estuaries can often increase nutrient loadings. Nitrogen and phosphorus tend to bind to organics and other trace elements; therefore, if organics and trace elements are present, nitrogen and phosphorus will likely be present.

Contributing Factors:

1. Nonpoint source nutrient loading
   a. animal facilities
   b. cropland
   c. residential development
   d. commercial areas
   e. septic tanks
   f. marinas
   g. golf courses
   h. forestry operations
   i. construction
2. Point source nutrient loading
   a. wastewater treatment plants
   b. industrial wastewater discharges
3. Atmospheric deposition
   a. industrial air discharges
   b. automobiles
4. Increased freshwater inflow and flushing rates
   a. dredging
   b. hydromodification (ditching, draining and channelization)
   c. urban development — residential, commercial and industrial sites
   d. weather
   e. soil conditions
5. Loading of organics and trace elements
   a. wastewater treatment plants
   b. animal facilities

B. Nutrient Recyling

Years of anthropogenic nutrient loading from point, nonpoint and atmospheric sources have resulted in an accumulation of nutrients in the sediments of North Carolina's estuaries. Many nutrients attach to soil particles that rinse into estuaries and settle to the bottom. These nutrients are often resuspended in the water column when the bottom sediments are disturbed by human actions and natural forces. Once resuspended, they become available for production and can result in algal blooms. Bottom sediments are often disturbed more easily in areas without aquatic vegetation. The vegetation serves to dissipate wave energy. Shoreline modification such as bulkheading can increase wave energy and thus contribute to nutrient recycling.

Contributing Factors:

1. Mixing of the water column and disturbance of bottom sediments
   a. weather
   b. dredging
   c. fishing practices
   d. boat and barge traffic
2. Loss of stabilizing vegetation including submerged aquatic vegetation (SAV) and littoral wetlands. See Problem Area V. Nursery Habitat Reduction for causes of loss of SAV.
   a. wetland alteration
3. Shoreline modification

C. Food Chain Disruption

Grazing fish and filtering organisms help keep algae and phytoplankton populations in check. Disruptions to the food chain that interfere with the balance between production and grazing and filtering organisms can result in excess algal production. For example, excessive removal of species at the top of the food chain will disrupt predator-prey relationships, often causing a decrease in species at other levels in the food chain. This "trophic cascade" can result in a reduction of grazing species, thus reducing the removal of algae from the water column. This excess algal production can sometimes result in a nuisance algal bloom.

Contributing Factors:

1. Reduction in species at the top of the food chain
   a. fishing practices
   b. dredging (loss of benthos can result in loss of fish that feed on them)

PROBLEM AREA III: SHELLFISH CONTAMINATION, DISEASE, KILLS AND CLOSURE OF SHELLFISH BEDS

Situation

Disease-causing bacteria and viruses that contaminate waters are a major concern in coastal North Carolina. Contamination of shellfish by harmful bacteria and viruses is a concern because of its effects on humans, who may consume the shellfish. It also has the potential to sicken or kill shellfish. Bacteria and viruses of concern include those that cause such diseases as typhoid and hepatitis in humans, shell disease in blue crabs and Dermo and MSX in oysters. These bacteria merit the scrutiny of resource managers since they can significantly impact fisheries productivity by reducing shellfish populations and excluding of many areas to harvest. The primary causes of shellfish contamination and disease are improperly placed or malfunctioning septic tanks, sewage treatment plants, discharges of human waste from boats, and runoff from animal feedlots and developed areas (Waite et al. 1994). Currently, about 56,000 acres of shellfish waters are permanently closed to commercial harvesting, and the affected area doubles with temporary closures after moderate rainstorms (Coastal Futures Committee 1994).

Although bacterial contamination of shellfish harvesting areas prevents human harvest and consumption, the shellfish remain in the water and continue to function normally. Disease, on the other hand, can actually kill the shellfish, thereby significantly reducing the stock. Similar to the fish kill and disease effects of pathogens, shellfish contamination and disease often result in chronic rather than acute responses, and these responses most likely indicate stressed environmental conditions. This stress could sublethally impact the reproductive and growth stages of shellfish, thereby reducing shellfish stocks and production (DMF 1991).

In North Carolina, shell disease resulting from environmental stress has recently been recognized as a common problem in crustaceans, particularly blue crabs, in certain areas of the Albemarle-Pamlico estuary. A lower immunocompetence to disease combined with the presence of opportunistic infectious agents seems to be the most probable explanation for shell disease in blue crabs (Noga 1990).

Since 1988, the parasitic diseases Dermo and MSX have been considered a severe problem in estuarine waters of North Carolina (DMF 1992). Infestations of Dermo have been more prevalent than MSX and have affected mainly oysters in the southern portion of the state (DMF 1991). Contamination and disease that result in the closure of shellfish beds, however, lead to a reduction in shellfish production and ultimately to economic problems for coastal regions.

Causes of Shellfish Contamination, Disease, Kills and Closure of Shellfish Beds

The three main causes of shellfish contamination, disease, kills and closure of shellfish beds in North Carolina estuaries have been identified as (A) pathogens, (B) oxygen deficit and (C) nuisance algal blooms. These three causes and the natural and anthropogenic factors that contribute to each cause are described below.

A. Pathogens (bacteria, viruses and fungi)

Fecal coliform, a bacterium that is found in the feces of humans and other warm-blooded animals, can leach through groundwater, travel via rivers, or be carried by stormwater runoff to coastal waters. Fecal coliform bacteria do not harm shellfish or consumers of shellfish; however, they indicate that human feces may be present. In addition to fecal coliform, human feces may also carry harmful pathogens that cause diseases such as polio, typhoid or hepatitis. Measurement of fecal coliform concentration is relied on as a mechanism to protect humans from eating contaminated shellfish. The tests that measure fecal coliform concentration cannot distinguish between human feces and feces from other animals, which do not present the same dangers. Therefore, some shellfish beds that are not harmfully contaminated may be closed to harvesting as a result of this public health protection mechanism.

Some fecal material is discharged directly to the water because of insufficient wastewater treatment processing or discharges from boats and marinas, while other fecal material can originate on land and wash into the water after rain in drainage from animal facilities. Malfunctioning septic systems may discharge fecal contaminants to groundwater that flows directly into adjacent coastal waters.

Fecal coliform and harmful bacteria do not live very long outside their natural environment. Vegetation can slow down the flow of surface runoff and filter it, often removing bacteria or detaining it long enough for the bacteria to die off. As a result, land clearing adjacent to coastal waters may result in contamination of shellfish beds even if no direct sources of fecal material are introduced. Forestry operations, mining, road-building and construction all enable coliform contamination.

Coliform bacteria, as well as many viruses and pathogens, usually live longer in fresh water than in salt water. Therefore, increased freshwater flow to shellfish areas that results from development and hydromodifications may increase the likelihood of shellfish contamination.

Some pathogens and viruses can harm or kill oysters; examples include parasitic infections such as MSX and Dermo. Pathogens can harm or kill clams as well. North Carolina's coast was declared a national disaster area as a result of the 1987 red tide. The red tide, which traveled up the coast from Florida with the Gulf Stream, was caused by *Gymnodinium breve*, a pathogenic marine dinoflagellate. Approximately 50 percent of commercially harvested oyster areas and 95 to 98 percent of clam areas were closed, resulting in an estimated loss of $26 million (Burkholder 1993a). Disease is much less of a problem for clams than it is for oysters. Ulcerative mycosis causes sores in blue crabs, and the toxin released by the dinoflagellate *Pfiesteria piscicida* is lethal to blue crabs (see Shellfish report in Appendix A).

Contributing Factors:

1. Nonpoint source discharges
   a. animal facilities
   b. residential development
   c. commercial development
   d. septic tanks
   e. marinas
   f. seafood processing
   g. boats and barges
   h. aquaculture
2. Land-clearing
   a. forestry operations
   b. mining
   c. road-building
   d. cropland
   e. construction
3. Point source discharges
   a. wastewater treatment plants
   b. seafood processing
4. Soil type (Sandy soils are less likely to filter out bacteria and viruses.)
5. See Problem Area I. Fish Kills and Disease, Cause C. Pathogens for additional sources that contribute to the presence of pathogens.

B. Oxygen Deficit

Dissolved oxygen is needed by all aquatic organisms. Maintaining suitable oxygen levels in shellfish areas is crucial, since most species are immobile and therefore unable to escape oxygen-starved waters. Chronic low dissolved oxygen can stress shellfish, thereby lowering their resistance to other environmental changes and making them more susceptible to disease.

Contributing Factors:

See Problem Area I. Fish Kills and Disease, Cause A. Oxygen Deficit.

C. Nuisance Algae Blooms

Quality, quantity and type of food supply are important to oysters and clams. The presence of too much food is a more common problem than the presence of too little; too much good food clogs the gills of shellfish (see Shellfish report in Appendix A). Some types of algae are inedible by shellfish, and others are toxic to them. Nuisance algae blooms, therefore, have the potential to clog the gills of shellfish and prevent them from obtaining proper sustenance.

Contributing Factors:

See Problem Area II. Nuisance Algae Blooms.

PROBLEM AREA IV: REDUCTIONS IN FISH STOCKS

Situation

Fish stocks are determined through statistical data collection and analysis of information such as amount of harvest, commercial and recreational fishing effort, size and age composition of natural stocks and harvests, fishing and mortality rates, migration patterns and rates, and reproductive parameters and success (DMF 1991).

To maintain adequate fish stocks, all stages of species reproduction (spawning, recruitment and juvenile survival) must successfully occur. Since fish reproduction and stocks are dependent upon habitat quality and quantity, environmental conditions and human activity, interference in any reproductive stage could significantly affect fish stocks (DMF 1991; Copeland and Steel 1991). For example, physical barriers to anadromous fish migrations in upstream rivers and tributaries, as well as the loss of variety and extent of seagrass beds, illustrate how human activity can directly affect historical spawning and nursery areas and influence reproductive cycles and fish stocks (Collier 1989).

Evidence also suggests that certain environmental and water quality conditions may influence recruitment and reproduction of fish. Water quality degradation and human-induced fluctuations in natural water quality parameters can affect both spawning and juvenile survival rates. In North Carolina, studies have shown an association between the abundance and viability of striped bass eggs spawned in the Roanoke River and the temperature and flow of the river (Rulifson 1993). In addition, overenrichment of upper estuarine regions by nutrients can increase algae growth, decrease available dissolved oxygen concentrations and available food sources for larval fish, and severely impede juvenile survival. A decrease in harvest of anadromous fish, including striped bass and herring in the 1970s and 1980s, indicates that some factor(s) is/are influencing the reproductive processes of anadromous fish (Rulifson 1991). Water quality degradation from nutrient overenrichment has been shown to stimulate the fish-killing toxic dinoflagellate, *Pfiesteria piscicida* (Burkholder et al. 1995).

Shellfish reproduction, including spat recruitment and development, can be affected by salinity and water temperature changes, increased turbidity, the condition of attachment surfaces, disease, the presence of other sessile organisms, direct physical disturbances and overharvesting. Currently, there are no definitive causal relationships between any water quality parameters and reductions in shellfish stocks. In North Carolina, however, the parasitic disease Dermo has been identified as a significant cause of mortality in juvenile oysters (Ortega et al. 1991).

In North Carolina, The Albemarle-Pamlico Estuarine Study's Status and Trends Report has identified a number of trends in commercial fisheries stocks (Copeland and Steel 1991):

1. Landings of major finfishes reached historic peaks in the late 1970s and early 1980s and have since declined, with the majority of our commercially important fish stocks stressed or depleted.

2. Landings of anadromous fishes have declined since the early 1970s or earlier.

3. Shrimp landings fluctuate widely depending on environmental conditions.

4. Landings of blue crabs reached peak levels in the early 1980s, declined, and have increased again in spite of a dramatic increase in fishing effort.

5. Hard clam fisheries are probably producing near their maximum potential.

6. Oyster landings have declined to the lowest levels on record.

7. Certain water quality concerns — including fish and crab diseases, loss of shellfish habitat, reports of fish kills, algal blooms and hypoxia — are becoming more frequent.

8. Downward trends in total commercial landings of edible finfish may indicate declining stocks.

9. Continuing stock declines attributable to pollution, environmental conditions and natural variations in abundance will likely be magnified by fish mortality caused by commercial and recreational fishermen.

Causes of Reductions in Fish Stocks

The five primary causes of reduced fish stocks in North Carolina have been identified as (A) the presence of toxicants in water and sediment, (B) increased turbidity, (C) oxygen deficit, (D) nursery habitat reduction, and (E) hormones. These five causes and the natural and anthropogenic factors that contribute to each cause are described below.

A. Presence of Toxicants in the Water and Sediment

The effects of toxicants on the fish community were identified by the Fisheries Team (see Fish report in Appendix A): There is concern about contamination of fish by metals, pesticides and other toxic substances. The presence of contamination is important relative to fish mortality as well as human health hazards and food chain implications. The only occurrences of fish contamination in North Carolina are in the immediate area of sources such as a wastewater treatment plant or industry. Contamination of fish by metals poses a threat to human health and possibly to other links in the food chain, but it is not a major threat to the fish themselves. Acute direct effects of golf course chemicals on fish in coastal waters have been witnessed. According to the U.S. Department of Agriculture, several fish kills in North Carolina have been caused by golf course runoff (Leavenworth 1992). However, there is little information about the chronic effects on fish that are exposed to a multitude of toxic substances. Nursery areas at the ends of canals are very susceptible to pulses of chemical runoff. Episodes of exposure to organics in these nursery areas can last up to 24 hours (see Shellfish report in Appendix A).

Contributing Factors:

See Problem Area I. Fish Kills and Disease, Cause B. Presence of Toxicants in the Water and Sediment.

B. Increased Turbidity

The effects of turbidity on fisheries were identified by the Fisheries Team (see Fish report in Appendix A): Turbidity can increase with siltation or sedimentation from runoff and erosion, disturbance and resuspension of bottom sediments, algal production or waste discharges. The source of turbidity determines the type and degree of effect it will have on fisheries. Increased turbidity can reduce light penetration and affect oxygen and temperature. Reduced light penetration can also isolate thermal heating to the upper layers of the water column, sometimes exacerbating stratification and the associated depletion of oxygen in bottom waters, directly harming fish that live near the bottom. Beds of submerged aquatic vegetation (SAV) can be diminished by the lack of light available for photosynthesis. Since SAV is important as habitat for fish, increased turbidity indirectly harms the fish community by reducing SAV habitat. Increased turbidity can directly interfere with the feeding of certain fish species by clogging the gills of filter feeders and deposit feeders and inhibiting feeding of species that depend on visual cues to detect food. Sediment deposits can bury fish eggs, making them nonviable and having a direct impact on fish reproduction. Sediment can also disturb the benthic community, thus affecting the forage base.

Contributing Factors:

1. Loss of submerged aquatic vegetation
   a. high nutrient concentrations. (See Problem Area II. Nuisance Algal Blooms, Cause A. Increased Nutrient Concentrations.)
2. Increased supply of sediment and solids from the watershed
   a. construction
   b. cropland
   c. animal facilities
   d. residential development
   e. commercial development
   f. industrial sites
   g. mining areas
   h. forestry operations
   i. road-building
3. Point source discharges of sediment and solids
   a. wastewater treatment plants
   b. industrial wastewater discharges
   c. seafood processing
4. Increased disturbance of bottom sediments
   a. boat or barge traffic
   b. dredging
   c. fishing practices
   d. hydromodification
5. Winds/currents
6. Hydrologic situation
7. Changes in freshwater/saltwater regime
8. Shoreline modification

C. Oxygen Deficit

The importance of oxygen to fisheries was also identified by the Fisheries Team (see Fish report in Appendix A): Most often, reduced oxygen levels stress fish and/or eliminate suitable habitat areas for certain species. However, there are also infrequent anaerobic events that cause fish kills. Reductions in dissolved oxygen levels can stress fish, causing them to be more susceptible to predation, bacteria, viruses and other mortality sources that are normally present in the environment. If oxygen levels drop severely, coastal waters become anoxic or hypoxic and fish kills can occur. Low dissolved oxygen can also kill invertebrates, a food source for fish. Energy transfer is reduced as a result of depleted oxygen, and growth and survival of fish are also reduced both directly and indirectly. Widespread areas of depleted oxygen can reduce the availability of habitat for some species. Estuarine systems naturally have high oxygen demand, however, anthropogenic loadings of oxygen-demanding waste, such as wastewater discharges and runoff from animal facilities, can substantially increase this demand. In addition, bottom sediments of estuaries are usually anoxic; activities that result in disturbance of these sediments can increase the oxygen demand.

Contributing Factors:

See Problem Area I. Fish Kills and Disease, Cause A. Oxygen Deficit

D. Nursery Habitat Reduction

The importance of habitat to fisheries was identified by the Fisheries Team (see Fish report in Appendix A): Habitat is important to fish, especially for food and shelter. Habitat requirements are stage-specific for many fish species. Estuarine habitats are usually of greatest importance to larval and juvenile fish. Habitat types are diverse and are the basis for a diverse fish community. Types of habitat include: marsh, seagrass, marsh creeks, mudflats, hardbottom (oyster reef), sandy bottom and the water column. Conversion or destruction of these habitats can affect the structure of the fish community. Some human activities can cause physical destruction of habitat, and other activities can change habitat characteristics, thus changing the type of fish community it can support. All environmental quality parameters are components of habitat. For example, increased nutrient loading, physical energy or turbidity can deteriorate seagrass beds, impairing their ability to provide forage and refuge. Similar to food availability, access is an important factor to consider in evaluating habitat. Almost all habitat areas are colonized by passive transport via currents and channels. An area may potentially be a good habitat, but without access it cannot be utilized by fish. There are only a few small entry points to the Pamlico Sound from the ocean. Without these access/migratory points, this area would not support such large fish populations. Even small changes in currents or hydrodynamics at these critical access locations can have vast impacts on the fish community.

Contributing Factors:

See Problem Area V. Nursery Habitat Reduction.

E. Hormones

The effects of hormones on fish were identified by the Fisheries Team (see Fish report in Appendix A): Hormones and other physiological factors affect growth, survival and reproduction and may affect wild fish populations when released into the environment. Animal operations (swine, poultry, cattle) discharge natural hormones in slaughterhouse waste products and are using increasingly more hormones in their production strategy. Some natural hormones, such as chemicals released from shellfish in aquaculture facilities, may also threaten fish. The potential for these hormones to be discharged from such facilities to coastal waters and to affect the growth, survival and reproduction of wild fish has not been addressed, but these substances could have significant effects on coastal fisheries.

Contributing Factors:

1. Discharges of wastewater or runoff that contain hormones.
    - a. animal facilities (feedlots)
    - b. animal processing plants
    - c. aquaculture facilities

PROBLEM AREA V: NURSERY HABITAT REDUCTION

Situation

Almost every species of aquatic marine organism relies on some aspect of North Carolina's estuarine region during its life cycle (Street 1989). Aided by tidal flow and wind-driven currents, aquatic organisms use every component of the estuarine system during reproduction: the offspring of oceanic species of fish rely on the estuarine area for development and growth; anadromous species of fish depend on the upper, less saline and freshwater areas of the estuary for both their spawning and juvenile development; oyster spat recruitment occurs in the deeper, more saline parts of the estuary; and blue crabs use low-salinity marsh creeks as well as seagrass meadows in high-salinity waters near inlets (Ortega et al. 1991; Street 1989). An analysis of every organism, although nearly impossible to accomplish, would illustrate that each species must spend some part of its life in a predefined region of the estuary in order to survive. In the Albemarle-Pamlico estuary alone, nearly every element of the approximately 3 million acres of wetlands and surface water is utilized as an integral component in the spawning, growth and development of 95 percent of North Carolina's commercially harvested species and 60 percent of the state's recreationally harvested species (Noble and Monroe 1991).

Even though the entire estuarine system can be regarded as an important natural aquatic habitat, the delineation and designation of different categories of nursery areas is inherently an anthropomorphic activity. In 1977, the North Carolina Division of Marine Fisheries defined nursery areas to be habitats, "in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young finfish and crustaceans spend the major portion of their initial growing season" (Noble 1991). Today, the DMF recognizes three types of nursery areas: primary, secondary and special secondary (Waite et al. 1994). Primary areas are those areas where postlarval and early juvenile development take place. Secondary areas, usually located adjacent to primary areas, contain mixed populations of juveniles and subadults (Street 1989). In the Albemarle-Pamlico estuarine system, primary nursery areas cover almost 25,000 acres, or 1.5 percent of the system's total water area (Waite et al. 1994). Anadromous spawning areas and shellfish beds are also identified as extremely important to the continued propagation of these types of marine species even though they are not officially designated as primary or secondary nursery areas by DMF (Ross et al. 1981).

The areas most critical to maintaining healthy and sustainable aquatic populations — marshes, seagrass beds, marsh creeks, mudflats, hardbottoms (oyster reefs), sandy bottom and the water column — are susceptible to conversion or destruction as a result of human activity. The resulting effects may have serious consequences on the structure of the fish community (see Fish report in Appendix A). Some human activities can cause physical destruction of habitat, and other activities can change habitat characteristics, thus changing the type of fish community it can support (see Fish report in Appendix A). For example, increased nutrient loading, direct physical disturbance or increased turbidity can deteriorate seagrass beds, impairing their ability to provide forage and refuge. In addition, since almost all habitat areas are colonized by passive transport via currents and channels, an area that may be a potentially good habitat may go unpopulated if access is blocked. Finally, a physical reduction in the geographic extent and amount of nursery habitat can result in increased competition among species (Waite et al. 1994).

As a result of the Albemarle-Pamlico Estuarine Study, studies have identified a relationship between the presence and extent of SAV, which is one of the most important nursery habitats, and some water quality parameters, most notably salinity and clarity associated with freshwater inflows and sedimentation. In the 10-year period from 1975 to 1985, almost 99 percent of the SAV biomass in the Pamlico River disappeared. Records also showed that the extensive and diverse communities of SAV in Durham Creek observed in 1973 had nearly disappeared by 1989 (Davis 1990). A loss of SAV may indicate a degradation in water quality that can directly affect aquatic organisms through direct loss of habitat or indirect chronic effects of contamination and pollution. Therefore, SAV may be an indicator of ecosystem stress as well as an indicator of fish nurseries.

Causes of Nursery Habitat Reduction

The five primary causes of nursery habitat reduction have been identified as (A) increased turbidity, (B) hydrologic imbalance, (C) increased nutrient concentration, (D) nutrient recycling, and (E) presence of toxicants in the water. These five causes and the natural and anthropogenic factors that contribute to each cause are described below.

A. Increased Turbidity (Physical and Biological)

Increased turbidity reduces penetration of light in coastal waters, thus reducing the ability of SAV to photosynthesize and grow. Sediment can also coat plant leaves, hampering their exchange of nutrients and minerals with the water.

Land-altering activities disrupt and expose soil, making it more vulnerable to erosion. Sediment from agriculture, land-clearing and development activities can reduce light penetration to submerged aquatic vegetation beds, affecting growth and distribution and causing a loss of nursery habitat area. Sediment deposited on the bottom of the estuary can also suffocate benthic organisms, which are food sources for juvenile and developing fish.

In addition to the direct effects of sedimentation on nursery habitat, sediment often contains attached particles of nutrients and toxic metals. These particles become dislodged as a result of the natural chemical reactions in the estuary. These substances are then deposited on the estuary floor or used by other organisms. Nutrients, in particular, are taken up by algae and may result in a bloom. Blooms, in turn, reduce oxygen concentrations, suffocating juvenile fish that are unable to leave nursery areas.

Sediment deposition and siltation caused by fishing activities such as clam kicking, trawling and dredging can bury shell material needed for larval settlement and suffocate live oysters and clams.

Contributing Factors:

See Problem Area IV. Reduction in Fish Stocks, Cause B. Increased Turbidity.

B. Hydrologic Imbalances (changes in the freshwater/saltwater regime)

Increased freshwater runoff due to development and hydromodifications can reduce the salinity of areas that support growth of SAV, affect shellfish habitat and cause changes in the plant community and wetland structure.

From 1948 to 1981, salinity levels showed a gradual long-term decline throughout most of the Pamlico Sound study area. The spatial variation in salinity trends was found to have an areal association with the level of anthropogenic drainage impact. Additionally, the salinity and drainage factors were related, temporally and spatially, to the spatial displacement of oysters.

Oyster displacement is an example of the biotic responses that often accompany salinity changes. A functional relationship exists among estuarine salinity, land use in adjacent areas and estuarine biota. For example, oyster recruitment is generally greater along eastern Pamlico Sound and Core Sound in the high salinity sites compared to the low salinity sites along the western side of Pamlico Sound.

Contributing Factors:

1. Increase in freshwater inputs due to land-clearing and development
   a. commercial development
   b. residential development
   c. industrial sites
   d. construction
   e. road-building
   f. cropland
2. Dredging of canals for navigation, flood control, etc.
3. Winds/currents
4. Hydromodification
5. Wetland alteration
6. Water withdrawal
7. Shoreline alteration

C. Increased Nutrient Concentrations (Nitrogen and Phosphorus)

Seagrass meadows provide enormous surface area for colonization by algae and animals that are food for valuable finfish, shellfish and waterfowl. Within the past few decades, thousands of hectares of seagrass habitat have been lost worldwide. Among the factors most frequently correlated with the disappearance of seagrass meadows are nitrate enrichment from sewage and agricultural drainage and shading caused by floating algae that are stimulated by nutrient loading (Burkholder 1993b). Recent experiments by Burkholder demonstrated that *Zostera marina*, the dominant seagrass along the North Carolina coast and an endangered habitat, is highly sensitive to nitrate at concentrations above minimal enrichment levels during high-temperature spring conditions (Burkholder 1993b).

"Under low water exchange simulating quiet embayments, eelgrass growth and survival significantly decreased at all enrichment levels, with most rapid decline at the highest nitrate loadings ... . the data indicate that water-column nitrate enrichment causes decline of eelgrass especially under increasing/high temperatures, as a direct physiological effect unrelated to algal light attenuation." (Burkholder et al. 1992)

Historic losses of SAV in North Carolina are reported in the following sources:

Davis, G. and M. Brinson. 1990. *A Survey of Submersed Aquatic Vegetation of the Currituck Sound and the Western Albemarle-Pamlico Estuarine System*. Report

No. 89-10. Raleigh, N.C.: Albemarle-Pamlico Estuarine Study.

Ferguson, R., J. Rivera and L. Wood. 1989. *Submerged Aquatic Vegetation in the Albemarle-Pamlico Estuarine System*. Report No. 88-10. Raleigh, N.C.: Albemarle-Pamlico Estuarine Study.

Ferguson, R. and L. Wood. 1994. *Rooted Vascular Aquatic Beds in the Albemarle-Pamlico Estuarine System*. Report No. 94-02. Raleigh, N.C.: Albemarle-Pamlico Estuarine Study.

Additions of nutrients, primarily nitrogen and phosphorus, from both point and nonpoint source pollution can cause thick mats of algae that can shade important seagrass species.

Contributing Factors:

See Problem Area II. Nuisance Algae Blooms, Cause A. Increased Nutrient Concentrations.

D. Nutrient Recycling

Nutrients that are stored in the sediments — especially nitrogen and phosphorus — have potential to be resuspended into the water column and become available for uptake by submerged aquatic plants that provide important habitat. Increased nitrate concentrations in the water column can have devastating effects on certain species of seagrasses (see previous section, Cause A. Increased Nutrient Concentrations).

Contributing Factors:

See Problem Area II. Nuisance Algae Blooms, Cause B. Nutrient Recycling.

E. Presence of Toxicants in the Water

Excess use of land-based herbicides that can wash into coastal waters, as well as application of herbicides in the water, can potentially kill important SAV species utilized as nursery habitats. Recent spraying of herbicides to reduce nuisance macroalga near Atlantic Beach and Morehead City, N.C., is suspected of causing a massive seagrass bed die-off approximately two weeks after the herbicide application (Burkholder personal comm. 1995).

Contributing Factors:

See Problem Area I. Fish Kills and Disease, Cause B. Presence of Toxicants in the Water and Sediment.

PROBLEM AREA VI: HUMAN HEALTH HAZARDS

The presence of any of the previous five conditions (fish kills and disease; reduced fish populations; shellfish contamination, disease, kills and closure of shellfish beds; loss of nursery habitat; and nuisance algal blooms) represents a degradation in water quality. In addition to impairing water quality, any of these conditions can have significant direct and indirect deleterious effects on human health (Copeland and Steel 1991).

Of these five water quality conditions, the three that impact human health the most are:

— fish kills and disease

— shellfish contamination, disease, kills and closure of shellfish beds

— nuisance algal blooms.

Since kills, disease, and contamination are symptomatic of poor ecosystem health, the same environmental stress factors that contribute to these problems can affect human health. For example, impaired water quality, toxic contamination, the presence of enteric bacteria, and the presence of certain pathogenic microorganisms all compromise human health. For example, organisms that cause fish disease, particularly bacterial organisms such as *Aaeromonas hydrophila*, may also be human pathogens. Such a determination is extremely important to protecting the health of coastal residents (Stewart 1987).

In addition, consumption of diseased or contaminated aquatic organisms can also cause illness and possible death in humans. Currently, about 56,000 acres of shellfish waters are permanently closed to commercial harvesting, and the affected area doubles when temporary closures are ordered after moderate rainstorms (Coastal Futures Committee 1994).

Causes of Human Health Hazards

The three main causes of human health hazards in North Carolina's coastal waters have been identified as (A) presence of toxicants, (B) pathogens, and (C) nuisance algal blooms. These three causes and the natural and anthropogenic factors that contribute to each cause are described below.

A. Presence of Toxicants in the Water

Certain metals, pesticides and other toxicants in the water can accumulate in the fatty tissue of fish and in the tissue of filtering organisms. In a study to determine the extent of fish contamination within the APES region, the N.C. Division of Environmental Management found only six of 420 fish fillets to contain mercury at concentrations at or above the FDA action level. However, four of the six came from the Chowan River at Riddicksville (DEM 1991). High percentages of detectable lead concentrations were found at four locations primarily around the Pamlico River estuary (DEM 1991). Researchers looked for the presence of 13 pesticides; nine were detected but none in concentrations at or above the FDA action levels. Results show that the primary toxicants of concern within the Albemarle-Pamlico estuarine system are mercury and dioxin (Cunningham 1992).

In North Carolina, consumption advisories are issued when fish are contaminated with elevated toxicant levels above approved FDA action levels. Advisories are a common practice in other states such as Florida and Michigan (Cunningham 1992). Warnings or limitations on fish consumption due to mercury and dioxin contamination occur in isolated areas of North Carolina. Contamination usually occurs near certain industrial activities, with the exception of the Lumber River Basin. The source of mercury contamination in the Lumber River Basin is currently unknown (Doll personal comm. 1995). The Environmental Epidemiology Section of the N.C. Department of Environment, Health and Natural Resources maintains the advisory list. As of May 9, 1995, waters in the coastal drainage area with advisories due to mercury contamination included the entire Lumber River Basin, the Waccamaw River in Columbus and Brunswick counties, and Black Lake in Bladen County. Advisories for elevated dioxin levels are listed for portions of the Albemarle Sound, Roanoke River, Chowan River and Neuse River, and the sections of Welch Creek that are in Beaufort, Martin and Washington counties.

Contributing Factors:

See Problem Area 1. Fish Kills and Disease, Cause B. Presence of Toxicants in the Water and Sediment.

B. Pathogens (bacteria, viruses and fungi)

Consumption of shellfish contaminated by harmful bacteria or viruses may cause serious illness and even death. However, no reported illnesses from eating contaminated shellfish have ever been linked to waters approved for harvest by the Shellfish Sanitation Branch of the N.C. Division of Environmental Health. Occurrences of illness have primarily been linked to illegal harvesting from waters closed to shellfishing and shellfish imported from outside the state (Robert Benton personal comm. 1995). With 56,000 acres of shellfish waters closed to harvesting and many more temporarily closed after rainfall, the potential for illness and death from contaminated shellfish consumption in North Carolina is significant. However, the state's current protection mechanism appears effective.

Recently, fishermen have reported having temporary foggy memory, chronic sickness with flulike symptoms and persistent open bleeding sores after wading in water or having substantial contact with water through handling fish and/or fishing gear. The areas where they have reported these experiences correspond to the locations of known toxic outbreaks of the recently discovered dinoflagellate, *Pfiesteria piscicida*. In addition, the symptoms that fisherman have reported match those experienced by JoAnn Burkholder and laboratory personnel at N.C. State University that were exposed to the dinoflagellate before the full extent of its toxic potential was known and adequate precautions were taken (Burkholder personal comm. 1995).

Contributing Factors:

See Problem Area 1. Fish Kills and Disease, Cause C. Pathogens for additional sources that contribute to the presence of pathogens.

C. Nuisance Algae Blooms

Of 144 species of blue-green algae found, 114 have produced asthmatic responses in humans during tests, with approximately 40 species causing acute asthmatic effects. Ingestion of and direct contact with blue-green algae blooms have been shown to cause gastroenteritis and a variety of other irritations (i.e. ear, nose and throat). Dinoflagellates are known for causing red tides, massive fish kills and shellfish poisonings that are toxic to humans. Paralytic shellfish poisoning can be fatal to humans in extremely small doses. Approximately 2,000 cases of human poisoning through fish and shellfish consumption are reported throughout the world annually. *Gymnodinium breve*, a pathogenic marine dinoflagellate, can cause respiratory irritation in humans that ranges from sneezing and coughing to bronchial constriction when cell fragments become airborne in sea spray. The 1987 red tide that traveled up the coast from Florida with the Gulf Stream didn't cause any human deaths in North Carolina because state agencies monitored and quickly closed shellfish beds. Serious illness and death can also result from consumption of shellfish that have accumulated domoic acid poison from toxic diatoms (Burkholder 1993a).

Contributing Factors:

See Problem Area II. Nuisance Algal Blooms.

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SHELLFISH TEAM

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Shellfish

As a first step in identifying the protection needs of shellfish, the shellfish team divided the estuary into habitat zones and identified the species associated with each zone. The team characterized shellfish by their multiple values as coastal resources and determined the criteria for maintaining their proper functioning. The team listed North Carolina's major coastal shellfish groups and the target species within each group. The groups include oysters, clams, blue crabs and shrimp. Many of these shellfish groups serve as indicators of zonation within the estuarine system, while others, such as the blue crab, utilize nearly the entire system.

In this section, each shellfish group is first examined individually to determine what thresholds are critical to maintain the survival and proper functioning of the target species within the group. Next, the overall function of the benthic community is examined to ensure that the parameters derived from the target species approach are adequate for maintaining the function of the entire community, including the vital interactions of its various components.

Included in this section is a list of the target species in each shellfish group, the function of each group as a coastal resource, the zones of the estuarine system that the target species occupy and what factors affect their function. Factors that affect their function are divided into biotic and abiotic, and the relative importance of each factor is ranked either **HIGH**, **MEDIUM** or **LOW**. Finally, the overall function of the benthic community, which includes shellfish, relative to the estuarine system is discussed. Four comprehensive habitat types are identified as necessary to maintaining North Carolina's shellfish. Recommendations for protecting shellfish and their habitats are included.

Oysters

Oysters are important commercially as food for humans. But less obvious is the importance of oyster reefs as habitat for shrimp, blue crabs and other shellfish. Reefs are vital components of estuarine habitats that support a wide variety of species, both commercial and noncommercial. Oyster reefs shelter animals, provide food for finfish and shellfish, and produce commercially valuable oysters. Oyster shells have commercial importance as a source of calcium in chicken feed and as a buffer to prevent acidic conditions in aquaculture facilities. Oysters enhance water quality by filtering out particulates and stabilizing and reducing suspension of sediment. They have also been used as water quality indicators for fecal coliform, metals and suspended particulates, and changes in abundance of oysters can indicate reductions in dissolved oxygen and changes in salinity.

Zone

In northeastern North Carolina, oysters colonize both the subtidal and intertidal zones; along the southeastern coast, they primarily occupy the intertidal zone. Spatially, estuarine waters with salinities of 5 to 10 parts per thousand to full-strength seawater (37 parts per thousand) are suitable for their survival.

Problem

The perceived problems with oysters include reductions in the total number of oyster beds in the estuary, increased areas with harvesting restrictions due to coliform contamination, and more frequent occurrences of oyster disease. Directly related to these concerns are increased turbidity, nonpoint source pollution (marinas, stormwater runoff), changes in salinity and trawling over oyster beds, which destroys the beds by fragmentation.

Abiotic Factors Affecting Oysters:

Water Quality

Temperature, Oxygen and Salinity — **HIGH**. These parameters have been evaluated by many other researchers and agencies. A literature search of current recommendations is necessary to determine the suitable ranges of these parameters.

Metals — **MEDIUM**. Concentration of metals in oyster tissue may not affect oysters themselves or functions of the oyster reef such as habitat for other species and water quality improvement. However, these contaminants can make oysters unsuitable for human consumption.

Toxicants — **MEDIUM**. Similar to metals. The concentration of some toxicants in oyster tissues can make them unsuitable for human consumption. However, other toxicants may kill oysters, resulting in loss of all their functions. Different toxicants such as hydrocarbons, pesticides and fungicides will affect various oyster functions.

Turbidity — **MEDIUM**. Increased turbidity, siltation or resuspension of particulates can indirectly affect oysters by changing the food supply. And oysters can be affected directly by increased suspended sediments that inhibit their feeding and bury their colonies, sometimes smothering them.

Flow (Hydrodynamics) — HIGH. Changes in flow dynamics can indirectly affect oysters by changing the food supply. Too much optimal food can clog gills, and not all algae are edible. Flow modifications can also change oxygen availability, salinity or temperature, thus threatening the area's suitability as oyster habitat.

Biotic Factors Affecting Oysters:

Habitat — HIGH. Oysters need a stable substrate upon which the larvae can settle, such as rock, pilings, shell debris or an existing oyster reef. Therefore, an oyster reef or a seed bed must already be present. The presence of pre-existing populations is also highly important for recruitment.

Recruitment — MEDIUM. Proximity and size of brood stock affects recruitment success. Recruitment success is also dependent on hydrodynamics and local water-flow conditions, particularly in marsh systems.

Food Supply — MEDIUM. Quality, quantity and type of food supply are important. The presence of too much food is a more common problem than the presence of too little; too much good food clogs their gills.

Predators — MEDIUM. Oysters are an important food resource for blue crabs and rock crabs. The oyster drill, *Urosalpinx cinerea*, can also be an important predator.

Biotoxins, Pathogens and Disease — HIGH. Coliform accumulation in oyster tissue warns of the presence of dangerous viruses and pathogens, thus making them unsuitable for human consumption. Some pathogens and viruses that are innocuous to humans can harm or kill oysters by causing diseases such as MSX and Dermo.

Clams

Target species of clams include: estuarine mud clams (*Rangia*), scallops (*Argopecten irradians*), hard clams (*Mercenaria*), soft shell clams (*Mya arenaria*), disk clams (*Dosinia*), Carolina marsh clam (*Polymesoda*), several potential aquaculture clam species, and key trophic species such as the "Baltic macoma" (*Macoma balthica*), ribbed mussel (*Geukensia*) and river mussels (*Unionacea*). Clams are similar to oysters in that they are important commercially as food for humans, help improve water clarity through their filtering mechanism, serve as water quality indicators for many pollutants and are an important food source for birds, blue crabs, fish, shrimp and other crustacean shellfish. However, they are not as important as habitat for other species, and they are not as effective at sediment stabilization as oysters.

Zone

These target clams species live in more varied zones than the oyster, including all zones of the estuarine system. *Polymesoda, Geukensia, Macoma, Mya, Dosinia* and *Mercenaria* colonize the intertidal zone of the estuary. *Macoma, Mya, Donsinia* and *Mercenaria* also do well in the subtidal areas of the estuary along with *Rangia*. *Unionacea*, river mussels, are located much farther upstream outside the tidal zones. The table below shows their locations relative to the three salinity zones: oligohaline (0-8 parts per thousand), mesohaline (8-15 parts per thousand) and polyhaline (15-37 parts per thousand). The bay scallop is restricted to the subtidal regions of the sounds where the salinity is high (30 parts per thousand or greater).

Problem

The biggest problem with clams is the slow decline of their populations. Habitat loss and alteration are of major concern in relation to population reductions.

Abiotic Factors Affecting Clams:

Water Quality

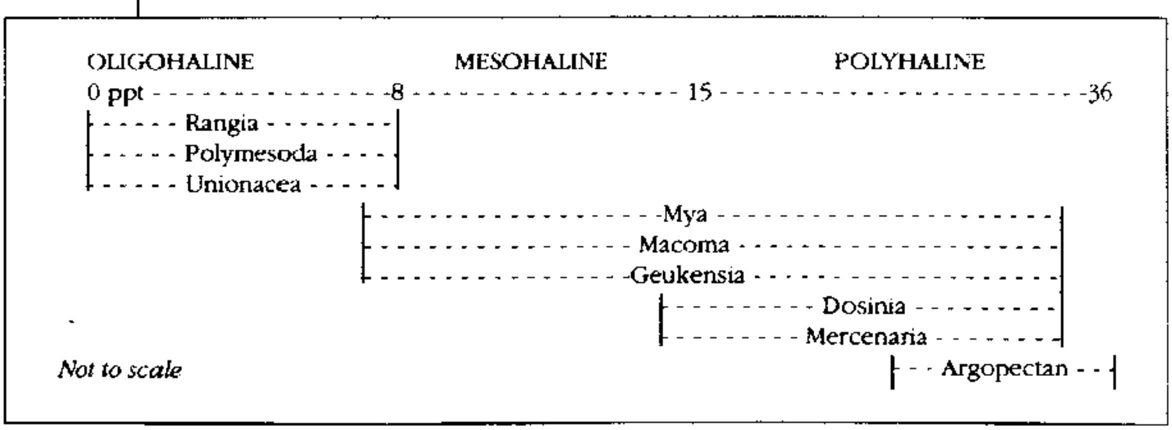
Temperature, Oxygen and Salinity — **HIGH**. Clams spread across a much wider salinity gradient than oysters. Again these parameters have been evaluated by many other researchers and agencies. A literature search of current recommendations is needed to determine the suitable ranges of these parameters for clams as well as for oysters.

Metals — **LOW**. As with oysters, concentration of metals in the tissues of clams may not affect certain functions such as water quality improvement; however, it can make them unsuitable for human consumption.

Toxicants — **LOW**. Similar to metals. The concentration of some toxicants in the tissue of clams can make them unsuitable for human consumption, while other toxicants may kill clams, resulting in the loss of all their functions. Different toxicants will affect various functions.

Turbidity — **HIGH**. Increased turbidity, siltation or resuspension of particulates can indirectly affect clams by changing the food supply. Sediment quality is important because of food supply and because of habitat. Whether or not an area is suitable for suspension-feeding or bottom-feeding depends on flow, sediment quality, phytoplankton production and the species of clam. Increased levels of suspended sediments may inhibit feeding. However, they are more resistant to burial than oysters due to their natural burrowing lifestyle (clams) or their ability to move short distances (scallops). Overall, turbidity is of high importance to clams.

Flow — **HIGH**. Flow and hydrodynamics are important to clams. Generally, they need a minimum level of flow to facilitate feeding and removal of waste products.



Biotic Factors Affecting Clams:

Habitat — MEDIUM. Clams, unlike oysters, do not need a seed bed for habitat and recruitment purposes. However, other organisms such as oysters and fish and vegetation are important components of their habitat. Oysters and vegetation provide refuge, and fish help disperse some clams such as *Unionacea*. The presence of pre-existing populations is important for habitat and recruitment; however, existing populations are comparatively more important for oysters than for clams because the oyster larvae require adult shell for attachment and metamorphosis into juveniles.

Recruitment — MEDIUM. Proximity and size of brood stock may affect recruitment success. Recruitment is of variable importance according to the local populations. The importance of annual recruitment success in maintaining the population is less important in long-lived species (*Mercenaria*) than in short-lived species (*Argopecten*).

Food Supply — LOW. Quality, quantity and nature of the food supply are important. However, it is unlikely that local species of clams and scallops are food-limited, therefore, food supply is of low importance at this time.

Predators — HIGH. Predation issues are different for clams than oysters. Many clams can escape predation by burrowing. However, *Macoma* and *Mya* get nipped because their siphons protrude above the sediment. During juvenile stages, numbers can be reduced severely because they are unable to burrow deep like larger clams.

Species Interaction — MEDIUM. Interaction with other benthos is relevant, including bioturbation caused by worms that resuspend the bottom, making the habitat unsuitable for clams.

Biotoxins, Pathogens and Disease — LOW to **MEDIUM**. The problem with bacterial contamination in clams such as *Mercenaria* and *Mya* is the same as it is for oysters. Some pathogens and viruses can harm or kill clams. Bay scallops suffered a large population drop due to the 1987 toxin-producing red tide bloom (Summerson 1990). Disease, however, is not nearly as much of a problem for clams as it is for oysters and is of low to medium importance. For scallops, it is of medium importance.

Clam species with unusual functions, needs or parameters that affect them:

Bay Scallops

Bay scallops are important commercially as food for humans, and their shells are sold for decoration. They play only a minor role in sediment stabilization. They are a very important food resource for the blue crab. Their habitat requirements distinguish them from other clam species. Bay scallops are epifaunal, meaning they live on the sediment surface by attaching to seagrass stems after metamorphosing on the bottom. They need three-dimensional structures on which to settle, such as oysters, macroalgae and debris. Flow is also very important to scallops because of transport of food and larvae. Scallops are more vulnerable to unsuitable water quality conditions than clams because of the limited ability of their shells to remain closed. Clams can stay closed for five to six days, whereas scallops can remain closed for only about a half hour. During a freshwater intrusion caused by a hurricane, for example, a clam will close and open later when salinity has risen. Scallops can't stay closed and are confined to low salinity water, where they are unable to osmoregulate.

Blue Crabs

Blue crabs are important commercially as food for humans. They are among the most important predators in the estuary, eating numerous other species of shellfish. Blue crabs resuspend sediment and other bottom particulates as they feed and burrow. This bioturbation function is important for sediment and nutrient cycling in the estuary because it exposes anoxic bottom sediments. Blue crabs create bioturbation pits that are important feeding areas for many fish. Blue crabs may also be indicators of "stressful" environments. For example, crabs collected from compromised environments show abnormally low levels of hemocyanin, an oxygen-binding blood protein. Suspected sources of stress are low dissolved oxygen, the presence of pollutants or disease. Another symptom of environmental stress is a high incidence of "shell disease," i.e. the formation of pits by localized bacterial degradation of the exoskeleton. Elevated frequencies of shell disease have been found in blue crabs and other crustaceans occupying benthic habitats that contain high levels of heavy metals.

Zone

Blue crabs occupy zones of the estuary that range from fresh water to marine and subtidal to intertidal, covering most areas of the system. The oligohaline, mesohaline and polyhaline areas are all important to the survival of blue crabs. Females and juveniles are less euryhaline (able to tolerate a wide range of salinities) than the males. Females stay in the more saline areas because that is where they have to reproduce. Their larvae cannot tolerate salinities of less than 20 parts per thousand. In contrast, the males travel far into the freshwater estuarine fringes in search of food. The juvenile stage is the most critical stage of the blue crab. During this stage seagrass beds and oyster reef are extremely important for habitat.

Problem

The problem with blue crabs and shrimp is the fear of crustacean fisheries failing without apparent warning, as has happened on the West Coast. There is currently not enough information available on blue crabs to qualify this concern. If a critical life stage of the blue crab is heavily dependent on a particular habitat or some other environmental criteria, then a population crash could be possible as a result of the habitat or environmental criteria being eliminated. More research needs to be done to evaluate the life stages of the blue crab and the criteria necessary to support each stage. Fishing pressure on blue crabs has not been quantified for North Carolina estuaries.

Abiotic Factors Affecting Blue Crabs:

Water Quality — Water quality is of lesser importance to blue crabs in comparison to oysters and clams, with the exception of salinity and dissolved oxygen. Water quality affects crabs more indirectly as it applies to seagrass beds and oysters, which are important to blue crabs for habitat and refuge. Some water quality changes that are generally considered negative may be beneficial to crabs. For example, increased turbidity directly improves the survival of juveniles by providing them with refuge to escape predation by other crabs. However, crabs are indirectly harmed by the negative impacts of increased turbidity on grass beds and oysters.

Temperature, Oxygen and Salinity — **HIGH**. Salinity is very important to the larval stage of crabs because they cannot tolerate low salinities. Various stages of the blue crab's life cycle are carried out in all three salinity zones of the estuary, including the oligohaline, mesohaline and polyhaline. Larvae emerge in the polyhaline, and as juveniles they move through the mesohaline. Female crabs stay in these two salinity regions because of reproductive needs. On the other hand, males migrate through all three zones in search of food. Therefore, it is necessary to maintain the salinity regimes of these areas. Crabs are less affected by low dissolved oxygen (DO), mainly because they are mobile and can move out of an area with low DO. However, oxygen depletion can eliminate important habitat areas. And if shallow water areas are altered or eliminated, then blue crabs are trapped in deeper waters with low DO.

Metals — **LOW**. Metals are of low importance to blue crabs because there are only localized areas where metals are present at levels high enough to harm them. However, elevated frequencies of shell disease have been found in blue crabs and other crustaceans occupying benthic habitats containing high levels of heavy metals.

Toxicants — **LOW**. Effects of toxicants on crabs are variable and to a large extent, unknown. Exposure to some toxicants may stress crabs, making them develop sores, while other toxicants may kill them. There is not enough information available to adequately address this factor. However, it is of low importance in North Carolina's estuaries.

Turbidity — **MEDIUM**. Increased turbidity improves the survival of juveniles by providing them with refuge from predation by other crabs. On the other hand, turbidity can kill seagrass and indirectly affect oyster reef, both of which are important habitat for blue crabs. Therefore, turbidity is of medium importance to blue crabs.

Biotic Factors Affecting Blue Crabs:

Habitat — HIGH. Oyster reef, seagrass and shallow sand are extremely important to blue crabs for refuge. Seagrass beds and oyster reefs are important as structures for new blue crab recruits. The oligohaline, mesohaline and polyhaline areas of the estuary are all important components of their life cycle. Expansive shallow water is important for habitat, especially in the absence of seagrass beds. And they prefer areas with fine sand over silt. Similarly, salt marsh is important to blue crabs in the absence of seagrass.

Predation — MEDIUM. Other crabs may be the only predator of blue crabs. The importance of cannibalism relative to the blue crab population is uncertain.

Food Supply — LOW. Prey sources are very important. Blue crabs are scavengers, but shellfish are an especially important portion of their diet. Reductions in clams may affect crab populations.

Biotoxins, Pathogens and Disease — LOW. There are pathogens that harm or kill crabs. For example, the recently discovered toxic dinoflagellate that is believed to be responsible for a large portion of fish kills in the Pamlico Sound has also been found to affect crabs. These dinoflagellates release a toxin that is lethal to blue crabs. Ulcerative mycosis has affected blue crabs, especially in the upper reaches of the Pamlico Sound. In North Carolina, shell disease has recently been recognized as a problem in crustaceans, particularly blue crabs, in certain areas of the Albemarle-Pamlico estuary. A lower immunocompetence among diseased crabs combined with the presence of opportunistic infectious agents seems to be the most probable explanation for shell disease in blue crabs (Noga 1990). Other diseases specific to blue crabs include gray crab disease, hymatadenium shell disease and others.

Incidental Harvest — MEDIUM. Harvest of blue crabs as bycatch by traps, baiting and netting for the soft-shell market or other fisheries has a small effect on crab populations.

Direct Fishing — MEDIUM. There is no strong evidence that commercial fishing has a significant (negative) effect on blue crab population size. Nevertheless, there remains a concern for the potential negative effect of overfishing because there must be a minimum number of adults needed to sustain the population. Current restrictions include a minimum size (5 inches from tip to tip of the two major lateral spines of the carapace) and a moratorium on egg-bearing females collected March through August in Hatteras, Ocracoke, Oregon, Drum and Bardeu inlets.

Shrimp

Target species of shrimp in coastal North Carolina include, white, brown and pink. Shrimp are important commercially as food for humans. In fact, these three species of shrimp are the state's most valuable fishery resource (Pendleton 1976). They are a strong link in the food chain and subsequently an important link in the flow of energy through the estuarine system. They eat detritus, and fish then eat them. By eating small invertebrates, they are also potentially important predators in the estuary.

Zone

Shrimp primarily utilize the polyhaline areas of the estuary, although white shrimp are more tolerant of fresh water and will venture into the mesohaline areas. In North Carolina, all three species, brown, white and pink, are found from Pamlico Sound south. They are primarily found in shallow subtidal zones. Adults reproduce offshore, and the postlarvae migrate into the estuary in search of food, favorable growing conditions and protection (refuge) (Pendleton 1976). The three target species, however, move into the estuary at different times. Once in the estuary, they migrate to the shallow estuarine nursery areas for food such as mollusks and crustaceans, which live in the bottom sediment, and detritus from submersed vegetation and marsh plants. After several weeks of feeding and growing in the estuary, they begin to move back to the inlets and river mouths. Pink shrimp will sometimes overwinter in Pamlico Sound by burrowing into the sediment; later they move toward the ocean. Those that reach the ocean begin moving south and to deeper waters, where they are soon caught by shrimpers (Pendleton 1976).

Problem

As with the blue crab, there is the concern for crustacean fisheries failing without apparent warning, as has happened on the West Coast. Also, there is not enough information available on the brown, pink and white shrimp to qualify this concern. A habitat or other criterion may exist that supports a critical life stage of these shrimp species and that may cause a crash if removed. More research needs to be done to evaluate the life stages of shrimp and the criteria necessary to support each stage. Fishing pressure on shrimp has also not been quantified for North Carolina estuaries. In the past, it has appeared that no matter how many shrimp were taken from the estuary, they always rebound. This could be because of their very short life cycle. This short life cycle could eliminate the possibility of fishing pressures ever causing a crash in North Carolina's shrimp populations.

Abiotic Factors Affecting Shrimp:

Water Quality — Water quality has an indirect effect on shrimp through alterations in habitat and food availability.

Temperature, Oxygen and Salinity — **HIGH**. Salinity is important to the overall distribution of shrimp. Suitable salinity zones for the various stages of their life cycle must be maintained, especially feeding areas such as seagrass beds. Shrimp utilize primarily the polyhaline and the mesohaline zones. Therefore, it is necessary to maintain the salinity regimes of these areas. Dissolved oxygen can be extremely important to shrimp in deeper systems, where low bottom DO can exclude shrimp. Since behavior, movement patterns and migration are affected by temperature, it can have a generalized influence on distributions of at least juvenile shrimp.

Metals and Toxicants — **LOW**. There is little information available to make conclusions about the influence of metals and toxicants on shrimp at the levels normally encountered in North Carolina's estuaries.

Turbidity — **MEDIUM**. Increased turbidity improves the survival of shrimp by providing them with refuge from predation by other organisms (Minello 1987).

Biotic Factors Affecting Shrimp:

Habitat — **HIGH**. Expansive shallow water areas are important to shrimp, as they are to crabs. The nature of the substratum is also important. Brown and pink shrimp prefer loose peat sediment and muddy-sand sediment; white shrimp prefer muddy sediments.

Oyster reefs, seagrass beds and salt marshes are also important, but not as important as they are to crabs.

Predators — MEDIUM. They are a food source for flounder, croaker and speckled trout.

Food Supply — MEDIUM. There is no evidence of food limitation for shrimp.

Biotoxins, Pathogens and Disease — LOW. There is no evidence of disease problems with shrimp in North Carolina. Pathogens are of only minor local importance to shrimp.

Overall Function of the Benthic Community

The benthic community has several important functions in the estuarine ecosystem, including nutrient recycling, trophic linkages, important fisheries, aesthetics, nursery habitat (i.e. oyster reefs), water clarification through filtering capacity, export of energy and organic carbon, and environmental indicators of pollutants and other water quality parameters (i.e. EPA's Environmental Monitoring and Assessment Program).

The benthic community should not be divided into separate components as it has been traditionally. Generally, the estuarine system has been broken into separate components including seagrass, salt marsh, hardbottom reef, oyster reef and tidal flats. Many similarities and differences exist among these areas. These areas all have very similar macrofaunal structure, but the cycling of nutrients is different. When these areas are considered separately, habitat boundaries are often drawn and the importance of interrelation among these areas is lost. For example, the seagrass community is not just the grass bed itself. For the seagrass bed to continue its function, the surrounding mudflat areas and the channel that provides flow into the area must also be maintained. This interrelationship between the grass bed, the mudflat and the channel is extremely important from a management perspective. For example, if a mitigation project requires the installation of a grass bed, but does not include a consideration of the habitat context, it will likely be an unsuccessful habitat mitigation.

In determining the criteria to maintain shellfish and the benthic community, habitat areas were looked at separately. But the proximity of the activities of the target species within these areas was considered so as not to draw habitat boundaries. The areas that were looked at include: seagrass and shallow sand; shallow sand; oyster and shallow sand/mud (90 percent of Pamlico Sound); and salt marsh with associated shallow nonvegetated muddy area and channel entrance. The importance of habitat and trophic structure through close examination of predator diversity is the primary focus of the Shellfish Team's report. The water quality criteria that should be maintained in these areas are better described by the Water Quality Team's report.

From a management perspective, several conditions should be maintained to continue proper functioning of the benthic community, including:

Habitat Diversity (Mosaic) — No single habitat area, such as seagrass beds, can support all the functions of the benthic community. Instead, a mosaic of all the habitat components must be maintained. The proportion and proximity of these habitats, such as seagrasses, sand flats, mudflats and salt marshes, etc. are important. Until more information on exact utilization patterns is obtained, we should preserve the current ratios regionally. A discussion of how to protect each habitat area is included.

1. Seagrass and Shallow Sand — Many seagrass beds are already protected because of their important function as nursery areas for larval fish, shrimp and blue crabs. But the shallow sand areas that immediately surround the beds and the associated currents and flow patterns are not protected. The shallow sand areas are where crabs forage for food (Powell 1994) and the flow patterns or currents facilitate the passive colonization of beds by larval organisms. For a seagrass bed to adequately continue its function as an important estuarine habitat, the surrounding shallow sand and flow characteristics must also be maintained.

• ***Recommendations:***

Protection of seagrass beds should extend 10 meters from the edge of the grass bed. No direct disturbances should occur to the bed or to this surrounding shallow sand area. In addition, no activities should occur that interrupt hydrodynamics, increase turbidity or nutrient loading or interfere with other water quality parameters to an extent that significantly inhibits or terminates the habitat function of the grass bed or poses harm to the animals using the bed. Proposed developments or activities should be evaluated for their potential disturbance both during construction and long-term operation. All mitigation projects should include consideration for the context of the grass bed to be established. Without an adequate shallow sand area and currents, re-establishment of grass beds for habitat will not be successful.

2. Shallow Sand — Expansive shallow sand areas are important to blue crabs for forage, especially in the absence of grass beds. Depth is the key characteristic that makes these areas suitable for blue crabs. In the Chesapeake Bay and near Wilmington, N.C., it was found that areas of less than a half meter in depth were typically utilized by blue crabs for forage (Powell 1994; Ruiz et al. 1993). In tidal areas, this translates to a 1-meter mean depth. Sand grain size is also important. In areas frequented by crabs, the sands are fine with a mean grain size of greater than 125 microns. Fine sands are more important than silts. By weight, these materials are 75 percent fine to very fine sands with typically one half of one percent organic carbon. Shallow sand areas are also important habitats for several clam species and penaeid shrimp. In certain parts of the state, any shallow water area with specific salinity and substrate characteristics is considered to be potential primary nursery habitat for shrimp.

• ***Recommendations:***

No net change in sedimentation and siltation to shallow sand areas should be allowed. No dredging, filling, channelization or other hydromodification project in these areas should occur that results in significant change in depth or sediment makeup.

3. Oyster Reefs and Shallow Sand/Mud — Recent research indicates that oyster reefs may be more important as habitat for shrimp, crabs and certain juvenile fish than they are as a direct commercial fishery. In Pamlico Sound and near Wilmington, N.C., crabs have been observed foraging between 2 and 5 meters off the continuous margin of oyster reefs (Powell 1994; West personal observation). To uphold the habitat function of oyster beds, it is therefore necessary to protect the shallow sand/mud areas surrounding the oyster reef. Oyster reefs consist of the oyster shells and some percentage of bare sand. If there is too much sand, the area is merely scattered shells. Scattered shell is found throughout much of Pamlico Sound and does not provide habitat like an oyster reef. Continuous clusters of oysters as small as one square meter in size, however, have shown habitat usage (Powell 1994). Live oysters are not necessary for these clusters to serve as habitat for fish, blue crabs and other shellfish.

• ***Recommendations:***

All oyster reefs worthy of protection should first be identified and mapped. Some oyster reefs are over 100 years old, while others last for only five years. The inventory of reefs would have to be updated accordingly. Protected and inventoried reefs should include all clusters of oysters (dead or alive) that are at least 1 square meter in size with a continuous boundary. No development or activities that would disrupt, fragment or otherwise physically destruct these beds should take place. As with the seagrass beds, this protection should extend to 10 meters outside the continuous boundary of the oyster cluster in order to protect the shallow sand/mud areas used by blue crabs, shrimp and juvenile fish for forage. In addition, each project or activity within close proximity to the reef should be looked at individually to determine if construction or long-term usage will disrupt flow, increase turbidity or alter water quality to an extent that buries the oyster bed; significantly impedes its habitat or food function; or poses harm to the animals utilizing the reef. A literature search of current recommendations for suitable temperature, oxygen and salinity ranges for oysters and clams should first be conducted. All mitigation projects should include consideration for the context of a bed to be established. Without an adequate shallow sand/mud area and flow supplied by currents, re-establishment of oyster reef for habitat or food will not be successful.

4. Salt Marsh With Associated Nonvegetated Muddy Areas — Salt marshes, as well as the nonvegetated muddy areas that surround them, are important to shellfish for habitat. High in organics and high in productivity, shallow mud areas are used similarly to the shallow sand areas of the estuaries. Secondary and tertiary channels of the shallow mud areas typically have a 1-meter mean water depth and are important primary nursery areas for crabs, shrimp, spot and croaker. Flushing, tidal patterns, water depth and oxygen are all important characteristics that make these areas suitable as nurseries. The unvegetated channels and shallow flats contained within the marsh system are, however, functionally more important than the outside adjacent flats that may occur between the marsh fringe and deep channels. The marsh thus functions as a refuge, both through shallow water channels and intertidal vegetation and a source of detrital food.

• ***Recommendations:***

No changes in depth of the muddy areas adjacent to salt marshes should be permitted. If depth is increased, the area is exposed to larger predators, which inhibits refuge for larval shellfish and fish. Accessibility of these areas is also crucial. An area may have a lot of production, but because of certain conditions such as temperature, oxygen or lack of physical access, shellfish may be excluded from the area. Each development or activity within close proximity of the area should be looked at individually to determine if construction or long-term use will disrupt flow exchange, lower dissolved oxygen, alter water quality or block off channel entrances to an extent that impedes the habitat function of salt marshes and the associated nonvegetated muddy areas or poses harm to the animals utilizing them. No activities or development should be permitted that alter flow dynamics to an extent that interferes with detrital accumulation or growth of vegetation in marsh areas. Developments immediately upstream of marsh areas should not increase runoff to salt marshes and surrounding mud areas. Mitigation projects should pay particular attention to channel and mudflat habitats.

Water Quality — From the community perspective, the maintenance of the proper salinity and flow regime is most important. If water quality is not improved, more problems will develop with the benthic community. The impacts of algal blooms, sewage discharges and sedimentation on the benthic community can be devastating. However, increased nutrient loadings and sedimentation aren't solely to blame for shellfish contamination, disease or population decline. Rather, numerous changes in water quality combined with changes in habitat cumulatively affect the shellfish and the benthic community.

Hydrodynamics — Inlets and flow hydrodynamics are crucial to maintaining food supply, proper access to feeding and nursery areas and a proper salinity regime for the benthic community. Flow speed and turbulence influence the deposition, resuspension and transport of food particles, detritus and inorganic particles that affect benthos in numerous ways. Benthic filter feeders are sedentary. Therefore, the rate at which food is supplied to them is a function of flow speeds. Changes in flow characteristics can negatively impact the benthic community.

Trophic Structure — The complexity or linkages of species (number of species multiplied by number of linkages) should be maintained rather than just the diversity (number of species).

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FISHERIES TEAM

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Fish

Coastal and estuarine fish communities are complex. Many different habitats and resources are required to maintain a diverse fish community, and North Carolina's coastal sounds and estuaries play an important role. Over 90 percent of all commercially and recreationally harvested fish spend a portion of their life cycle in the estuary. Both natural and human-induced influences on the estuarine system can affect the fish community. Development, tourism, boating and fishing along North Carolina's coast continue to increase as population grows. Individually these changes may seem small, and it is often assumed they have little or no impact on fisheries. However, the cumulative impact of these changes can have a substantial effect on the estuarine system and coastal fisheries.

In this phase of the study, the criteria needed for maintaining North Carolina's fisheries as a coastal resource were determined. For this process, it would be useful to describe a specific fish community to be supported, protected and managed. However, it is difficult to define the "ideal" fish community. Even under natural conditions, it fluctuates over time. Similarly, the list of desirable fish species also fluctuates. Using a historical perspective on fish communities for this definition is also difficult because the currently available data provide only a snapshot of the suspected long-term fluctuations. However, it is generally understood that changes in certain parameters such as salinity, temperature, oxygen, habitat or food availability can negatively impact fish communities. Human activities that occur on land and in the water can also contribute to these changes. Estuarine fish are extremely resilient. They are usually both euryhaline (able to withstand a broad range of salinities) and eurythermal (able to tolerate a broad range of temperatures). However, extreme changes in these parameters can take certain species beyond their threshold of tolerance, subsequently shifting the species composition of the fish community. An area may be altered so that it is no longer suitable for a particular species of fish, yet at the same time it becomes ideal for another species. These shifts may be desirable or undesirable.

Following is an outline of specific conditions and problems that affect the fish community. The relative importance of each condition is ranked **HIGH**, **MEDIUM** or **LOW**. However, all conditions are likely to be extremely important depending on the location and timing of their occurrence within the estuarine system. Discussions regarding variability of importance according to zone, location and time are included for several factors. For example, certain locations within the estuarine system, such as inlets and channel entrances to shallow bays, are important passageways for fish and their food resources. If changes in or near these passageways occur during critical periods such as during recruitment, even short-term transient changes can have long-term consequences to fish populations. Changes that are beneficial during one time period may be extremely detrimental during another time period. In addition, the effects of all these parameters vary in North Carolina's estuarine system because of the large degree of variability among estuarine segments. Geochemistry, biology and current patterns are important factors that vary widely in different parts of the estuary and can affect the result of certain changes.

Also included is a list of the natural and human factors that contribute to the problems that affect fish. These contributing factors are not discussed in great detail but are merely listed to provide the Environmental Systems Team with some insight as to what activities should be included in their analysis of the entire system. Because the estuarine system is so complex and expansive, including major water exchanges from rivers and the ocean, and because many fish are mobile, impacts can extend over a large area. And changes occurring in a given area often cannot be traced to a single local use. Many of the conditions and factors are interrelated. Some of these interrelations are discussed.

Turbidity (Direct/Indirect)

Turbidity can increase as a result of siltation or sedimentation from runoff and erosion, disturbance and resuspension of bottom sediments, algal production or waste discharges. The source of turbidity determines the type and degree of effect it will have on fisheries. Increased turbidity can reduce light penetration and affect oxygen and temperature. Reduced light penetration can isolate thermal heating to the upper layers of the water column, sometimes exacerbating stratification and the associated depletion of oxygen in bottom waters and directly harming fish that live there. Beds of submerged aquatic vegetation (SAV) can be reduced by the lack of available light for photosynthesis; this impediment is caused by both reduced light penetration and blanketing of plant stems by silt and particulates. SAV is important to fish for habitat. Therefore, increased turbidity indirectly harms the fish community by reducing SAV habitat. Increased turbidity can directly interfere with the feeding of certain fish species by clogging gills of filter feeders and deposit feeders and inhibiting feeding for those species that depend on visual cues to detect food. Sediment deposits can bury fish eggs, making them nonviable and having a direct impact on fish reproduction. Sediment can also disturb the benthic community, thus affecting the forage base. However, if algal production is the source of turbidity, some fish species benefit because they are better able to avoid predators or find food. In general, from a fisheries perspective, increased turbidity is a problem of **MEDIUM** severity in North Carolina's coastal waters. It is most important in the mesohaline or high salinity regions of the estuaries because of its effects on seagrass beds in these locations. Turbidity is also of importance in the oligohaline zone of the upper estuary and is more directly related to land use and erosion. It is of least importance in the mid-salinity region because turbidity is pervasive because of natural mixing processes in these areas due to wind exposure.

Contributing Factors:

— Sediment loads from forestry, agriculture, construction and urban areas

— Circulation or resuspension of bottom sediments from such natural occurrences as winds and such human disturbances as dredging or fishing practices (i.e. clam-kicking, trawling)

Recommendations:

• Best management practices (BMPs) for various land uses

• Water management for agriculture and forestry

Oxygen (Direct)

Most often, reduced oxygen levels stress fish and/or eliminate suitable habitat areas for certain species. However, infrequent anaerobic events also cause fish kills. Reductions in dissolved oxygen levels can stress fish, causing them to be more susceptible to predation, bacteria, viruses and other mortality sources that are normally present in the environment. If oxygen levels drop severely, coastal waters become anoxic or hypoxic and fish kills can occur. Low dissolved oxygen can also reduce important food sources for fish, such as immobile invertebrates. Energy transfer is reduced as a result of depleted oxygen, and growth and survival of fish are also reduced directly and indirectly. Expansion of areas with depleted oxygen levels can reduce the availability of habitat for some species. Estuarine systems naturally have high oxygen demand. However, loadings of oxygen-demanding waste such as wastewater discharges and runoff from animal facilities can substantially increase this demand. In addition, bottom sediments of estuaries are usually anoxic. Activities that result in disturbance of these sediments can increase the oxygen demand. In general, reduction of dissolved oxygen levels is a problem of **HIGH** importance in our coastal waters. The geographical extent, frequency and occurrence of anoxia and hypoxia should be reduced.

Contributing Factors:

Physical

— Salinity
— Temperature
— Circulation/wind (weather)
— River flow

Biological

— Oxygen consumption due to external organic carbon loadings from pulp mills, animal facilities and other oxygen-demanding wastes.

— Oxygen consumption due to internal decay of algae, aquatic vegetation and other organic material. Often a cycle of nutrient loading results in algal blooms that consume oxygen when they die and decay. Sources of these excess nutrients include wastewater discharges, agricultural runoff and other nonpoint sources.

Recommendations:

• Reduce loadings of oxygen-demanding wastes to the estuarine system, especially near key habitat areas. Most areas of the estuary are, however, key habitat areas.

Temperature (Direct)

All organisms have an optimum temperature range. Estuarine species are usually eurythermal, thus having a wide range. However, rapid temperature fluctuations or temperatures outside the preferred range can cause mortality, stress, reduced growth and loss of energy reserves. Temperature decreases may be more detrimental than increases. More importantly, temperature affects habitat availability. Fish utilize areas of optimal temperature, particularly during spawning, and will abandon areas with temperatures outside their preferred range. In general, temperature effects are of **LOW** importance in coastal North Carolina. There are some areas where thermal impacts to fish are a localized problem such as near an industrial discharge or coolant water intake and/or discharge. Thermal shocks to fish can also occur at the heads of bays during periods of heavy runoff or heavy discharges. Large land-clearing activities can intensify the severity of these shocks. These shocks are more pronounced during temperature extremes in winter or summer, often having detrimental effects on species such as sea trout and sea turtles. Temperature changes are most important in shallow oligohaline areas. Activities that restrict water movement in these shallow areas can result in containment of solar heating, which increases oxygen demand. Increases in warmer freshwater flows to these areas can exacerbate stratification. Surface waters can become the only layer with adequate oxygen for fish, but the temperature may be too hot, eliminating suitable area and causing stress. In addition, elevated temperatures can increase growth of nuisance algae that rob water of oxygen needed by fish.

Contributing Factors:

— Impoundments, other flow reductions or activities that restrict water movement can result in containment of solar heating, thus causing temperatures to increase in localized areas, especially shallow areas.

— Industrial discharges

— Cooling water intakes (if species are drawn in) and thermal discharges

— Impediments to currents

— Large-scale land-clearing for such uses as agriculture

Recommendations:

• Prevent activities that restrict water movement in shallow areas.

• Manage land use practices (e.g. land-clearing) to prevent summer runoff temperature increases greater than 2 degrees Celsius and winter decreases greater than 2 degrees Celsius.

Food Availability (Indirect)

Fish may go through a number of developmental stages, and their food requirements change during these different stages. Changes in the type and quantity of available food will affect the structure of the fish community. However, total fish productivity will usually remain about the same. Specifically, shifts in food type or availability affect growth and survival of fish. Food availability is a factor of **LOW** importance and is primarily an indirect effect of other disturbances or conditions. Many of the factors important for sustaining healthy fish populations are also necessary for their prey. Light, temperature and salinity affect algal composition and production, which is the basis of the food chain. Therefore, changes in these parameters can translate up the food chain. Many fish are adapted to particular types of prey, so conditions that affect the composition, abundance and distribution of prey will indirectly affect fish. Food quality is probably more important than food quantity, but it is species-dependent. Although plenty of algae may be readily available, many types of algae are not suitable as fish food, and other types are toxic to fish. In the case of filter feeders, changes in physical energy may change the particle sizes available, thus affecting the animals' filtering and feeding capacity. Changes such as these that affect fish populations at the producer level will transfer up the food chain. Other factors to consider include suitability and access of the area for consumers of the food resource. An area may have a lot of production, but because of certain conditions such as temperature, oxygen or lack of access, fish may be excluded from the area. Just because an area has abundant prey doesn't mean there will be high fish production.

Contributing Factors:

— Changes in physical characteristics listed under Oxygen (salinity, river flow, etc.) that affect the fish prey community or access to food resources.

Recommendations:

• Give equal consideration to impacts on invertebrates and noncommercial/nonrecreational fishes when establishing regulations.

Habitat (Indirect)

Habitat is a factor of **HIGH** importance to fish, especially for food and shelter. Habitat requirements are stage-specific for many fish species. Estuarine habitats are usually of greatest importance to larval and juvenile fish. Habitat types are diverse and are the basis for a diverse fish community. Types of habitat include: marsh, seagrass, marsh creeks, mudflats, hardbottom (oyster reef), sandy bottom and the water column. Conversion or destruction of these habitats can affect the structure of the fish community. Many human activities can cause physical destruction of habitat, and other activities can change habitat characteristics, thus changing the type of fish community it can support. All the other factors discussed in this fisheries section are components of habitat. For example, increased nutrient loading, physical energy or turbidity can destroy seagrass beds, reducing their ability to provide forage and refuge. Similar to food availability, access is an important factor to consider in evaluating habitat. Almost all habitat areas are colonized by passive transport via currents and channels. An area may potentially be a good habitat, but without adequate access it cannot be utilized by fish. There are, for example, only a few entry points to the Pamlico Sound from the ocean. Without these access/migratory points, this area would not support such large fish populations. Even small changes in currents or hydrodynamics at these critical access locations can have vast impacts on the fish community. Migratory and access routes are important considerations in all habitat preservation, restoration and creation efforts.

Contributing Factors:

— dredge and fill of wetlands and marsh areas

— channelization for drainage improvements, access or navigation

— diversion of flow for irrigation or water supply

— diking of canals

— construction and use of bulkheads, piers, bridges, groins, jetties, moorings and other man-made structures

— increased nutrient and sediment loads from point and nonpoint sources

— increased resuspension of sediment and mixing of the water column by boat traffic

— beach nourishment

— fishing practices, including clam-kicking and trawling

— recreational boating

Recommendations:

• Decisions regarding permitting must recognize local and cumulative impacts of habitat loss. The amount of available habitat is finite and has been excessively reduced. The permitting process needs to be modified to restore specific habitats and ***increase*** available habitat.

Salinity (Direct/Indirect)

Estuarine fish species are euryhaline (tolerant of a wide variety of salinities). However, the freshwater/saltwater regime affects many habitats within the estuarine system. Extreme and rapid changes in this regime can result in loss of habitat, particularly nursery areas, thus indirectly causing shifts in the fish community. Often, changes in salinity can improve conditions for pathogens, increasing the disease occurrence among fish populations. For example, ulcerative mycosis primarily affects young fish in areas of low salinity during the months of May and June (Noga 1993). In addition, some chemicals are toxic in salt water but not fresh water. Most fish are mobile, but sometimes they are trapped in unsuitable conditions. Changes in salinity can directly harm these organisms. In general, acute and sustained changes in the freshwater/saltwater regime should be avoided. Salinity is the main buffer system for coastal waters, preventing acidic conditions. Increased freshwater inputs could result in acidic conditions that are unsuitable to certain species of fish. Salinity is closely associated with river plume dynamics. Drainage of surface water from upland areas into nursery areas through man-made ditches and canals has been shown to create unstable salinity conditions when rainfall exceeds one inch in a 24-hour period. And brown shrimp, spot, croaker, southern flounder and blue crab prefer nursery habitats with no man-made drainage and stable salinity patterns (Pate 1981). Increases in freshwater flow can exacerbate stratification because the warmer, less dense freshwater flows on top and traps the cooler, heavier salt water below, preventing mixing. Overall salinity is of **MEDIUM** importance to coastal fish populations.

Contributing Factors:

— increased freshwater runoff from loss of wetlands, land-clearing and development (increase in impervious surface)

— flow diversion for agriculture or water supply

— dredging of canals for navigation or flood control

— dikes or barriers that change hydrodynamics

Recommendations:

• Regulations must consider cumulative impacts from runoff and changes in hydrodynamics and prevent substantive changes.

Currents (Flow/Hydrodynamics) (Indirect)

Certain locations in the estuarine system are important migrational points for fish. For example, inlets are narrow entrances between the estuary and the ocean that are extremely important access points for fish at various life stages, especially estuarine-dependent species. Channels provide fish access to small embayments where important food resources and refuge are located. Passive transport by currents and flow facilitates most of the colonization of these areas by fish and their food resources. Changes in these bottlenecks, or access points, can affect recruitment in new areas. Without current transport, larval fish and planktonic food resources can't access these habitat areas. Estuarine current dynamics affect food availability, recruitment and larval transport to nursery areas. Therefore, changes in current dynamics can shift the fish community and reduce fish populations. The timing of these changes is often crucial. Short-term transient changes can have long-term consequences if they coincide with the recruitment season. Some activities that change current and flow dynamics, such as dredging or dredge disposal, may have minimal impact at one time of year but be detrimental at another. Current dynamics also affect salinity and oxygen and therefore can affect the suitability of habitat. Changes in current dynamics are of **MEDIUM** to **HIGH** importance in our coastal waters.

Contributing Factors:

— flow diversion for agriculture or water supply

— dredging of channels and canals for navigation or flood control

— other dikes, jetties, piers, docks, underwater structures, berms or barriers that change the hydrodynamics of the estuary

— dredge disposal

Recommendations:

Regulations must consider cumulative impacts from runoff and changes in hydrodynamics and prevent substantive changes.

Predators and Competitors (Indirect)

Species-specific interactions are important to maintaining trophic balance of the fish community. Shifts in habitat, water quality or fishing that result in the decrease of a certain fish can change the species composition, thus altering the balance of the food web. For example, removal of an important predator species that keeps a grazer species in check may result in depletion of food resources important to other juvenile fish. Many commercially unimportant fish species are important components of the food web and are therefore necessary for maintaining trophic balance. For example anchovies, silversides and other small forage fish are important prey for bluefish, flounder and other predators. For this reason, effective fisheries management calls for a multispecies approach, not just single-species management for high profile fish. Changes in one species may have a ripple effect in the community. Predator and competitor interactions within the fish community and food web are of **LOW** to **MEDIUM** importance.

Contributing Factors:

— commercial and recreational overfishing and selective fisheries habitat destruction or alteration

— changes in any of the parameters here identified as affecting fish communities (i.e. salinity/freshwater regime, current or flow hydrodynamics or turbidity)

— fishing techniques and gear types

Recommendations:

• Use a multispecies approach to fisheries management.

Fishing Mortality (Direct/Indirect)

Fishing has a direct and major effect on fish populations and is of **HIGH** importance to maintaining coastal fisheries. Overfishing combined with other pressures (changes in salinity, lack of oxygen or loss of habitat) represents a cumulative impact on the fish community. Increased fishing mortality can also indirectly affect the fish community by triggering changes in other parameters such as predation/competition interactions. If, for example, a key species is removed, there will likely be a shift in the trophic balance of the system. Bycatch of nontargeted species in commercial fishing operations is also an important source of fish mortality (Murray et al. 1991). Many important juvenile commercial and recreational fish are caught as bycatch in fisheries directed at other species. Some fishing practices such as dredging and trawling may indirectly harm the fish community by destroying habitat (Upton 1992). In addition, fishing practices and certain fishing gear types will disturb bottom sediments, which, as mentioned earlier, can increase turbidity and oxygen demand. The impacts of uncontrolled and unselective fishing can outweigh all the other factors included in this section, not only because of the direct effect on fish, but because of the effects of fishing practices on habitat and water quality.

Contributing Factors:

— overfishing by both recreational and commercial fishermen

— bycatch

Recommendation:

• Coastal Zone Management should

obtain review authority over certain Marine Fisheries Commission decisions.

Disease (Indirect)

Diseases can kill fish or may make them unsuitable for market. Disease is of **LOW** importance as a direct effect on fish populations and is usually a consequence of other parameters previously discussed. However, recent evidence shows that many fish diseases such as ulcerative mycosis are a cumulative response to stress. The significant increase in incidence of disease in coastal fish populations is strong evidence of increasing cumulative ecosystem stress. Changes in salinity, temperature, oxygen or other parameters can stress the fish and make them more susceptible to disease organisms that are normally present. In addition, changes in these parameters and others such as nutrient loading may create an environment more suitable for disease organisms, thus increasing the exposure of fish.

Contributing Factors:

— stress from changes in environmental parameters (salinity, oxygen, temperature or the presence of toxics)

— changes in environmental conditions that make an area more suitable for disease organisms

Recommendations:

• Use incidence of fish kills and disease as an indicator of system stress; reduce cumulative impacts to mitigate stress.

Toxicants

There is concern for contamination of fish by metals, pesticides and other toxic substances. The presence of contamination is important relative to fish mortality as well as human health hazards and food chain implications. Contamination of fish is of most importance to human consumption, but, overall, it is of **LOW** importance to maintaining a healthy fish community. NOAA's National Status and Trends Program indicated no "high" concentrations of monitored metals and toxics in tissues of bottom-feeding fish and shellfish or in sediment samples at five North Carolina locations (NOAA 1990). The only occurrences of fish contamination are in the immediate area of a source such as a wastewater treatment plant or industry. Contamination of fish by metals poses a threat to human health and possibly to other links in the food chain, but it is not a major threat to the fish themselves. North Carolina has witnessed some acute direct effects on fish in our coastal waters such as fish kills from golf course pesticide use (Leavenworth 1992), but there is little information about the chronic effects to fish that are exposed to the multitude of toxic substances. Nursery areas at the ends of canals are very susceptible to pulses of chemical runoff. Episodes of exposure to organics can last up to 24 hours. In addition, other factors such as oxygen and salinity affect chemical toxicity, solubility and cycling. Chemical cycles are highly dependent on the oxygen conditions in the upper reaches of the estuaries (Sunda and Huntsman 1989). Anoxia cycles make various chemicals more soluble. During an anoxic period, metals or chemicals that have previously precipitated out and are stable on the bottom may be redissolved into the water column, thus re-exposing fish.

Contributing Factors:

— the presence and proximity of numerous point and nonpoint sources of pollution to coastal waters

— agricultural, golf course and other urban use of pesticides

— pulp and paper mills

— urban runoff

— wastewater treatment facilities

Recommendations:

• Biological indicators should be used to determine hazardous levels of toxics instead of just considering sediment and water column concentrations. Biological indicators should include fish, zooplankton and species representing the entire food web. Activities that generate potentially hazardous quantities of metals, pesticides or other toxicants should not be located immediately upstream of primary or secondary nursery areas (see discussion in the Water Quality Summary under B. Presence of Toxicants in the Water and Sediment). Use and discharge of metals, pesticides and other toxic or potentially toxic substances should be minimized in the estuarine system.

Hormones

Hormones and other physiological factors affect growth, survival and reproduction and may affect wild fish populations when released into the environment. Animal operations (swine, poultry, cattle) discharge natural hormones in slaughterhouse waste products and are using increasingly more hormones in their production strategy. Some natural hormones, such as the chemicals released from shellfish in aquaculture facilities, may also threaten fish. The potential for these hormones to run off or be discharged from these facilities to coastal waters and the possibility of them affecting the growth, survival and reproduction of our fisheries have not been addressed but could have significant effects on coastal fisheries. Therefore, the importance of hormones to coastal fish populations is unknown.

Contributing Factors:

— the presence and proximity of animal operations and processing plants to coastal waters and their specific use of hormones

— aquaculture discharges

Recommendations:

• Evaluate and monitor the potential effects of natural hormones and ones introduced by humans.

• Review the proximity of animal operations, animal processing plants and certain aquaculture facilities and the potential impacts of runoff from these facilities to important fish habitats.

Conclusion

Because of the complex interactions between fish populations and both their abiotic and biotic environments, it is often difficult to quantify or even identify the specific consequences of a particular action. Regulations implemented during the past 20 years have not prevented significant damage to fisheries habitat and some fish populations. If we wait for scientific study to decipher these linkages, we will lose much of our coastal resources. A risk-aversion approach is needed: The impact of all factors suspected of contributing to coastal declines should be reduced until a positive response is seen.

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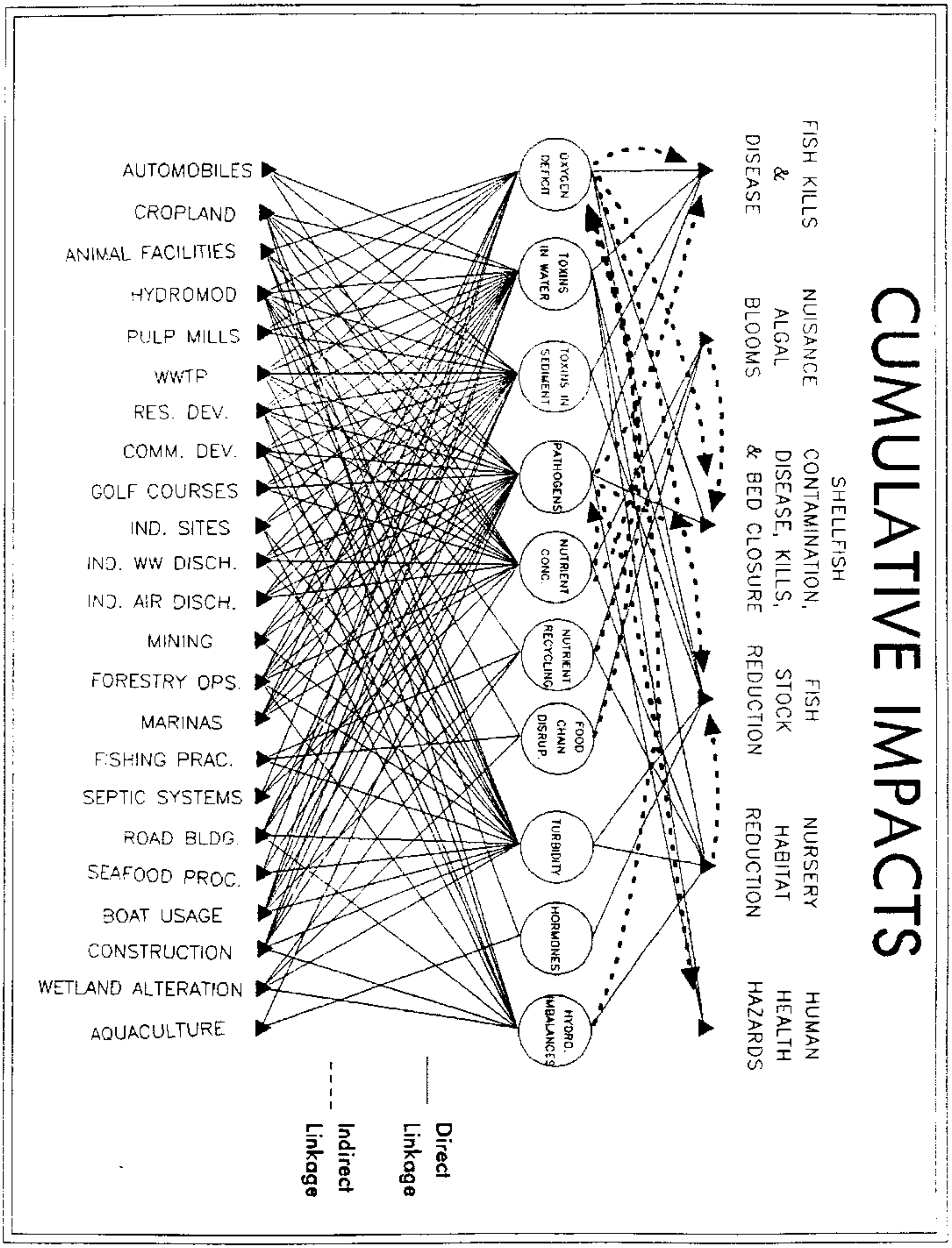
Appendix B

LINKAGES BETWEEN COASTAL RESOURCE QUALITY AND LAND USES AND HUMAN ACTIVITIES

Introduction

In designing a management strategy to protect coastal resources from the secondary and cumulative impacts of development, it is first necessary to investigate all the known linkages between various land uses and human activities and the problems we are currently experiencing along our coast. In determining the proper function of their resource, the Water Quality Team identified six problems that indicate degraded water and aquatic resource quality. They listed all the known causes and contributing factors to these six problems. The diagram presented on page B-2 indicates the result of their evaluation. This diagram successfully shows the complexity of how all human activities are cumulatively resulting in the changes considered environmental degradation. Additional diagrams displaying the linkages specific for each separate problem area and each individual land use or human activity have also been provided. This should help isolate the various components resulting in or related to cumulative impacts. These diagrams are designed to help aid in decision-making processes relative to cumulative impact management. These diagrams allow the decision-maker to focus on a particular problem of concern or a specific land use or human activity in question, while also considering the full extent of cumulative impacts.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FISH KILLS & DISEASE
NUISANCE ALGAL BLOOMS
SHELLFISH CONTAMINATION, DISEASE, KILLS, & BED CLOSURE
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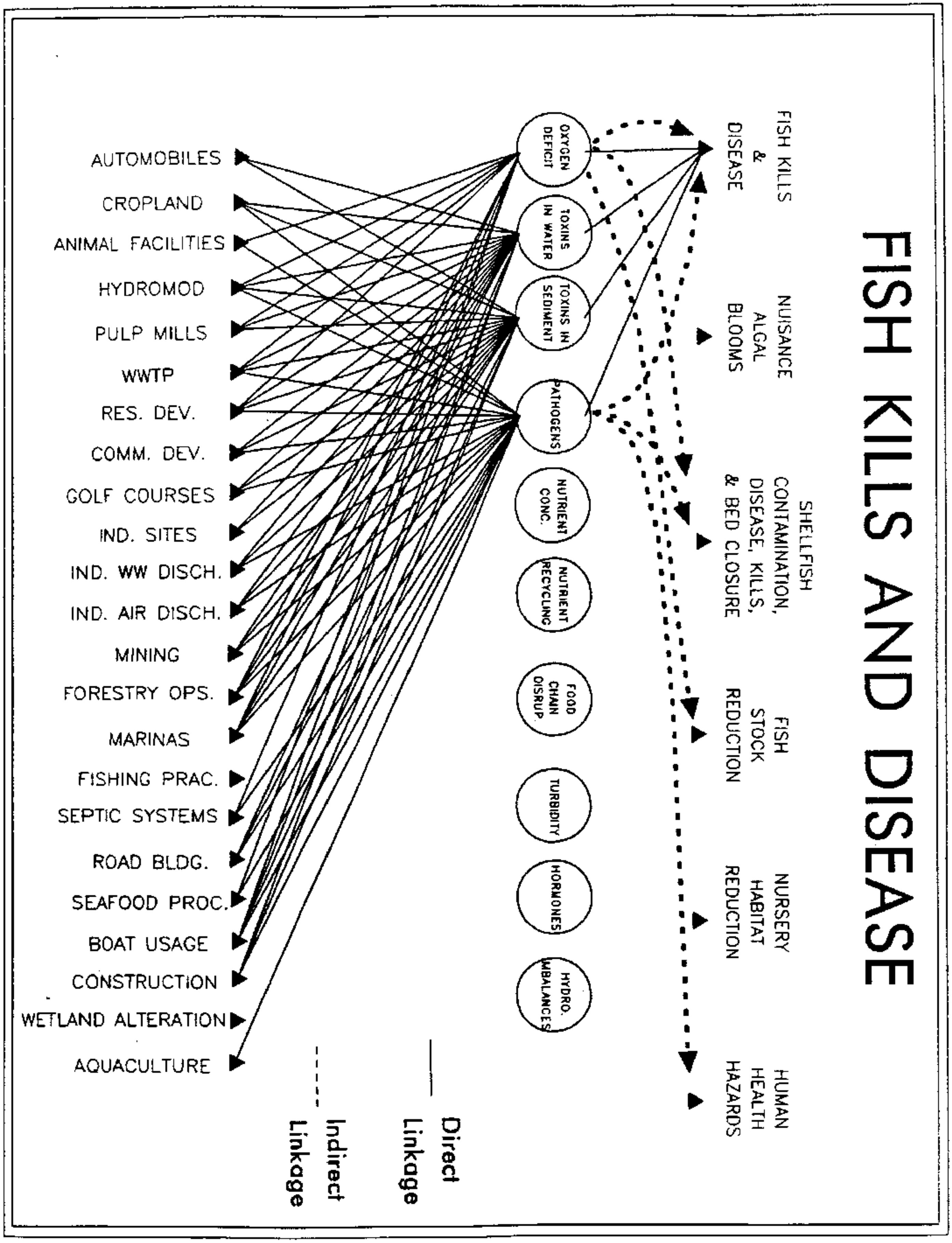
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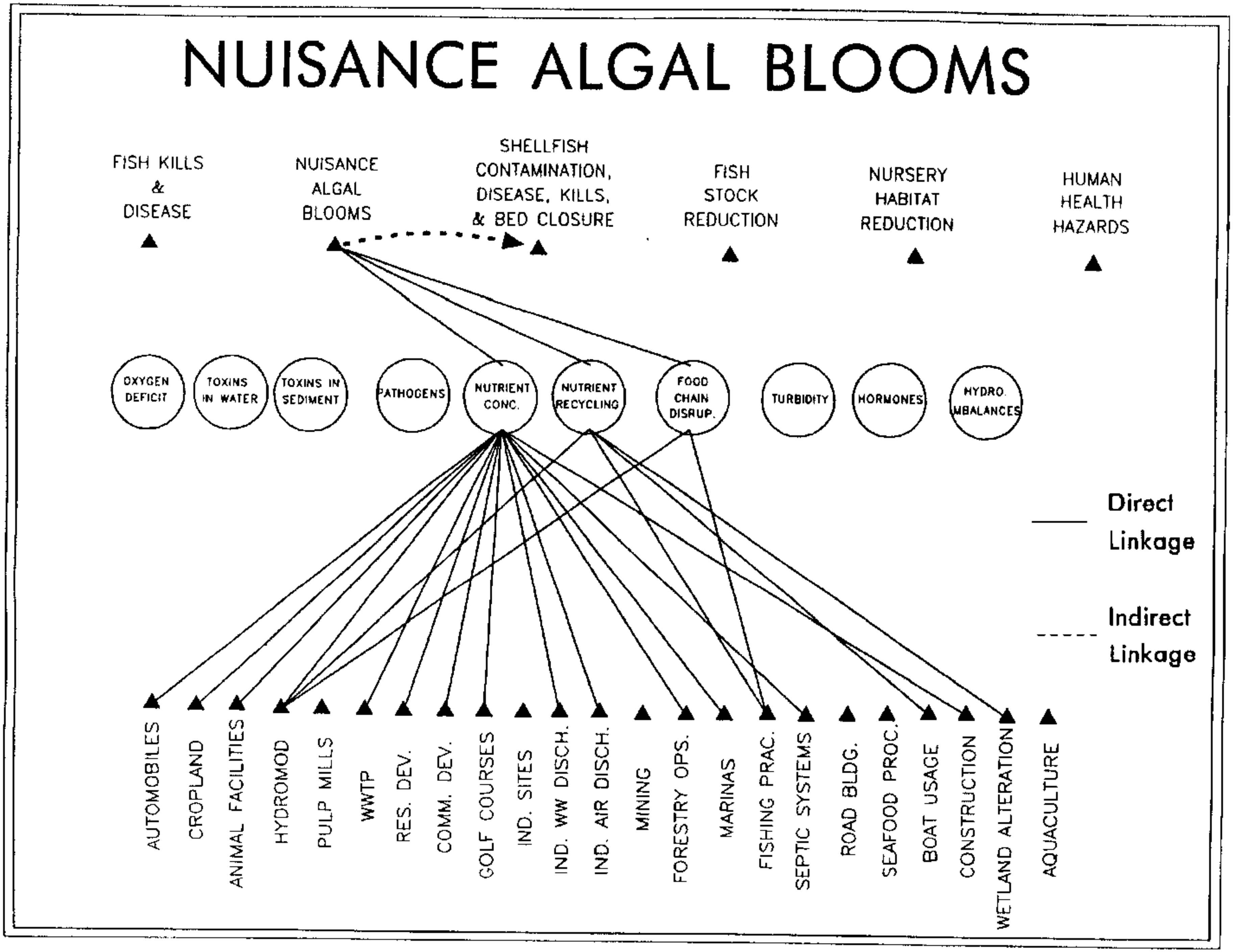
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FISHING PRAC.
SEPTIC SYSTEMS
ROAD BLDG.
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CONSTRUCTION
WETLAND ALTERATION
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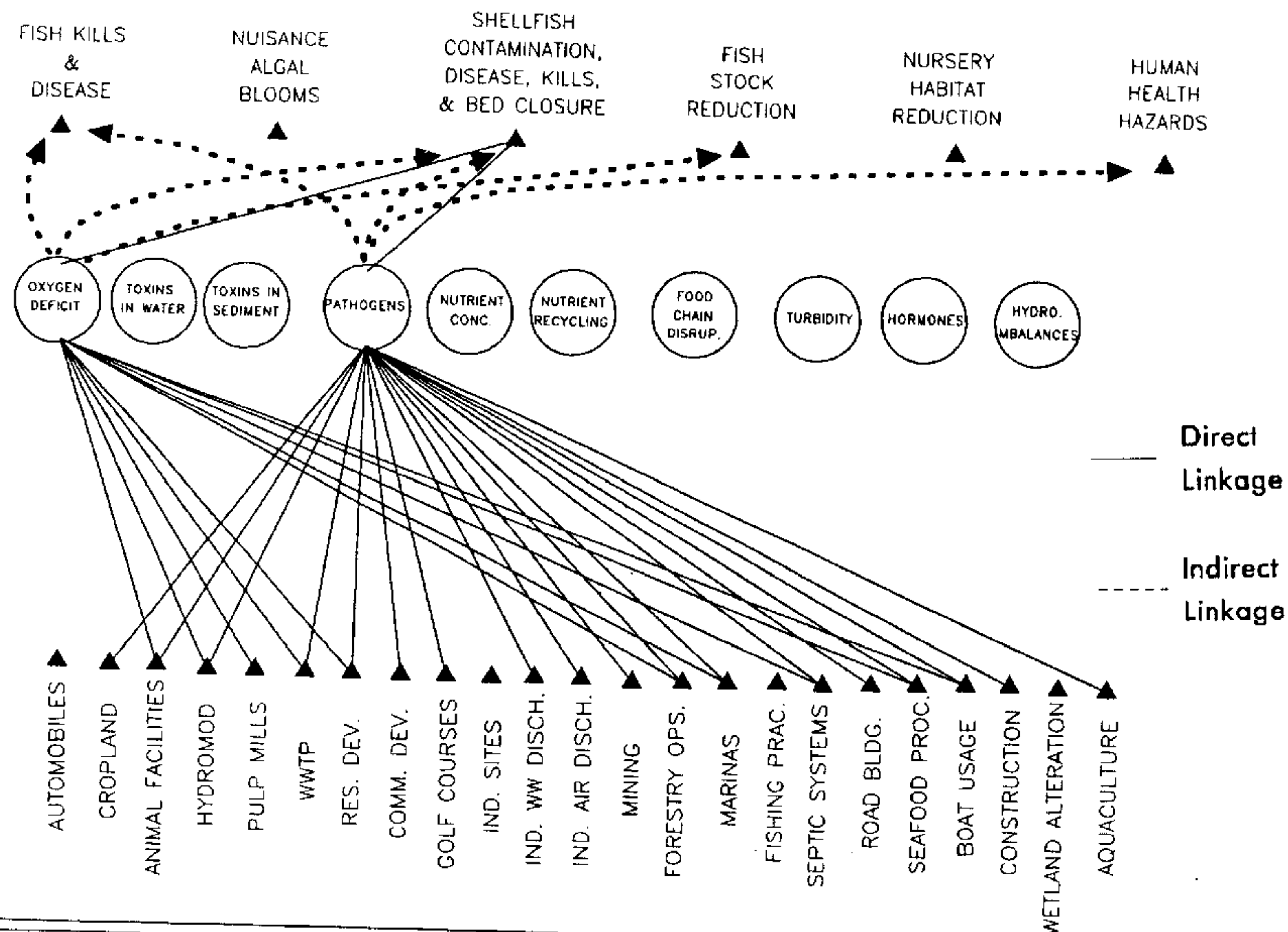
SHELLFISH CONTAMINATION, DISEASE, KILLS, & BED CLOSURE



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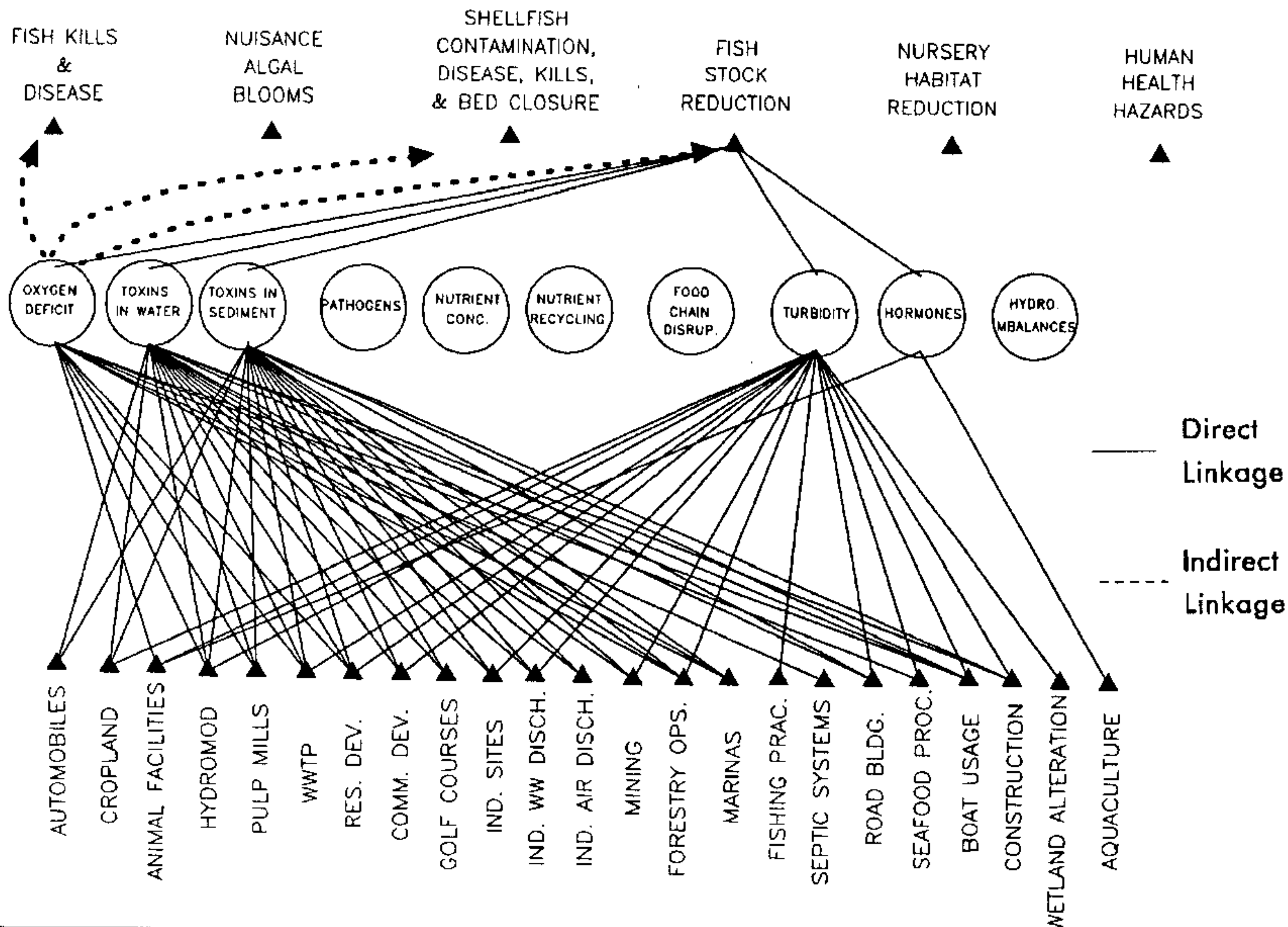

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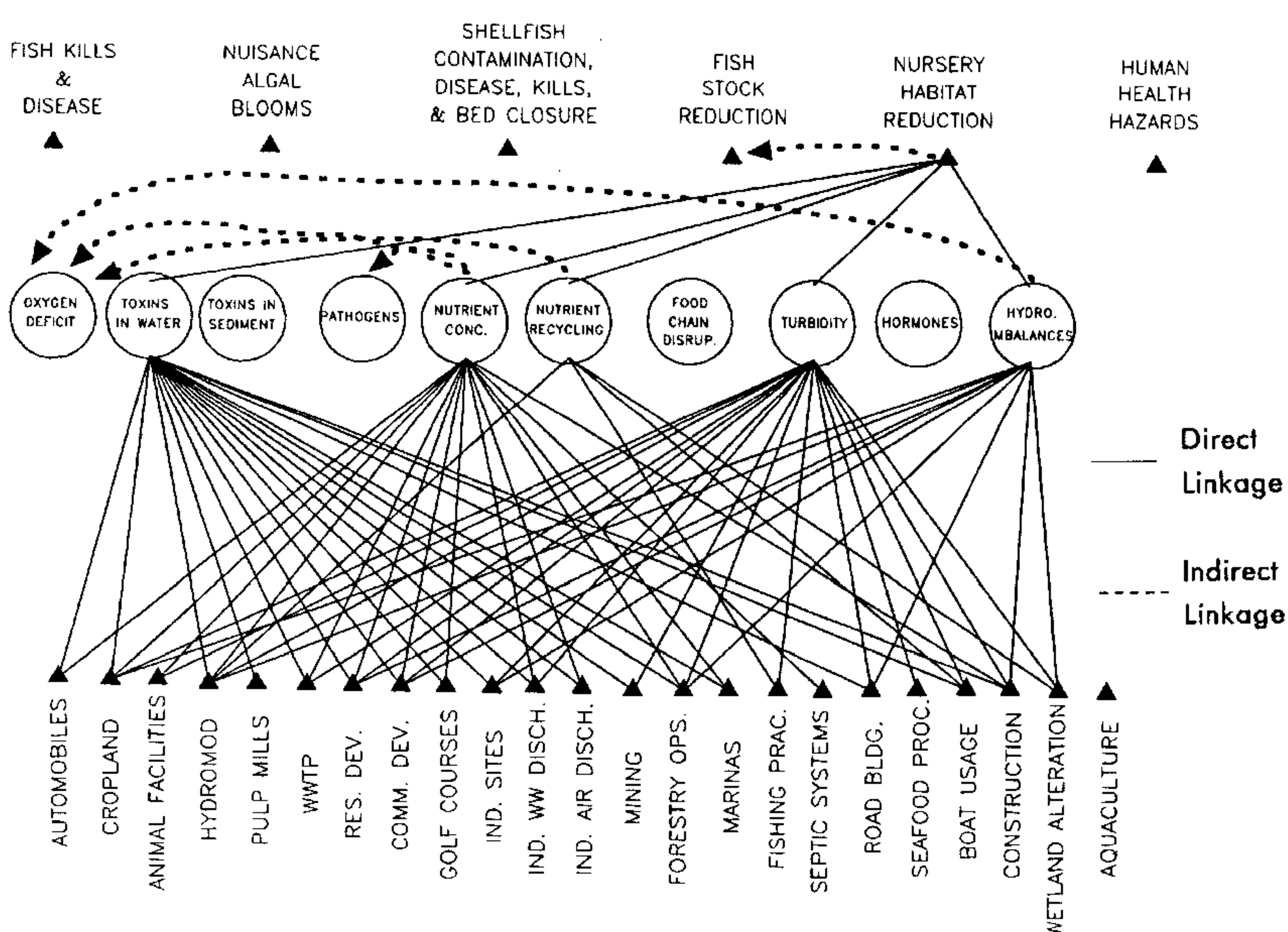

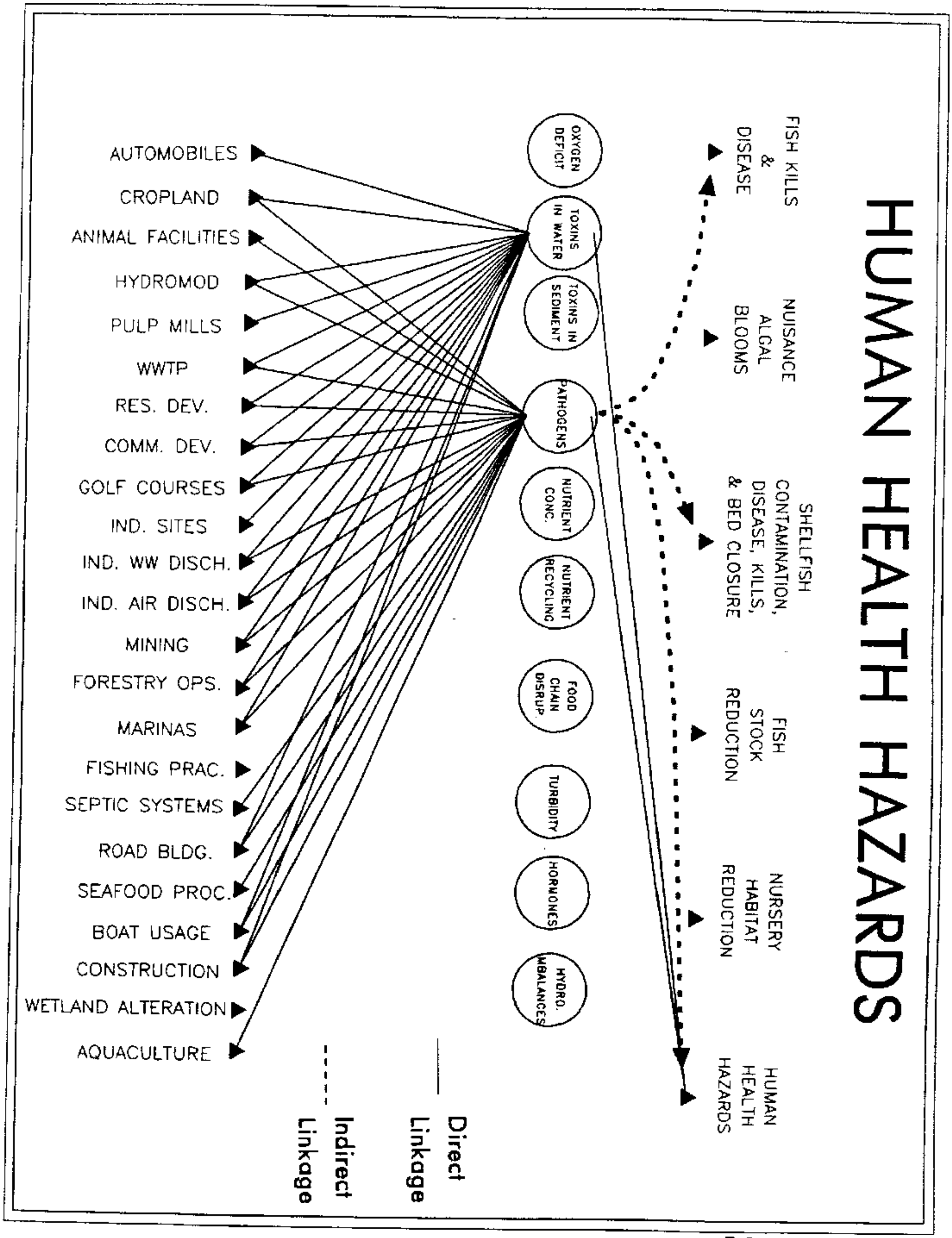
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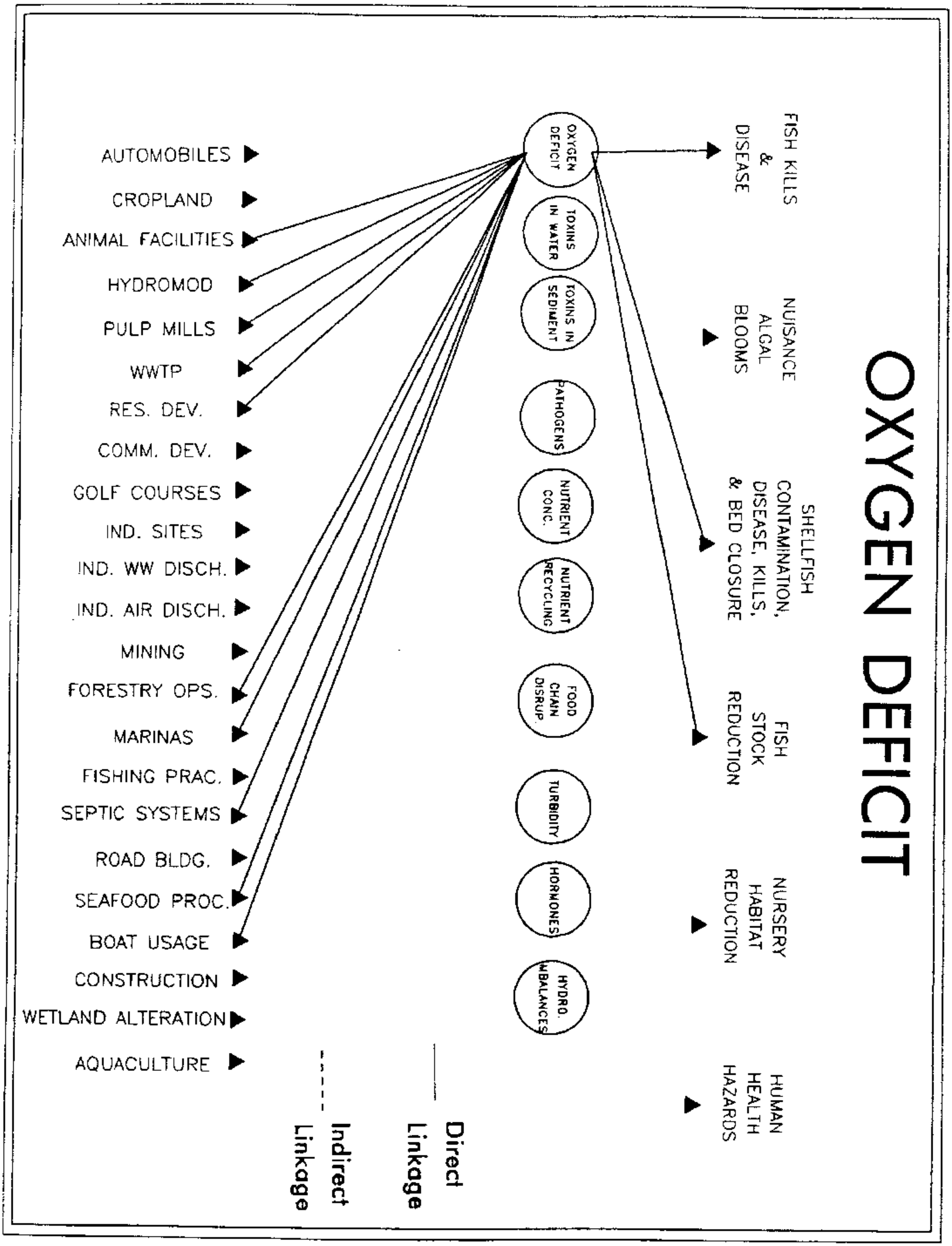
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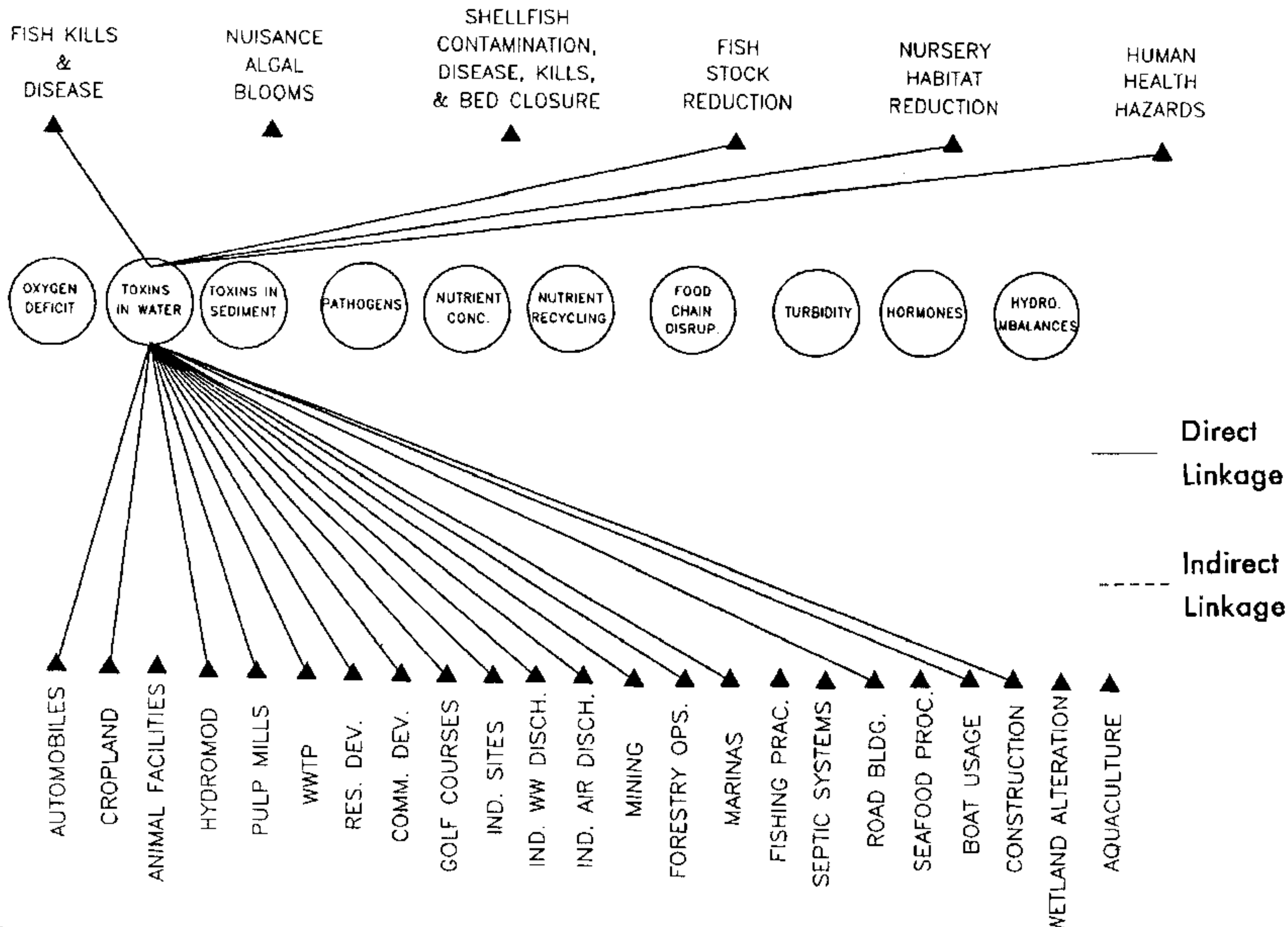

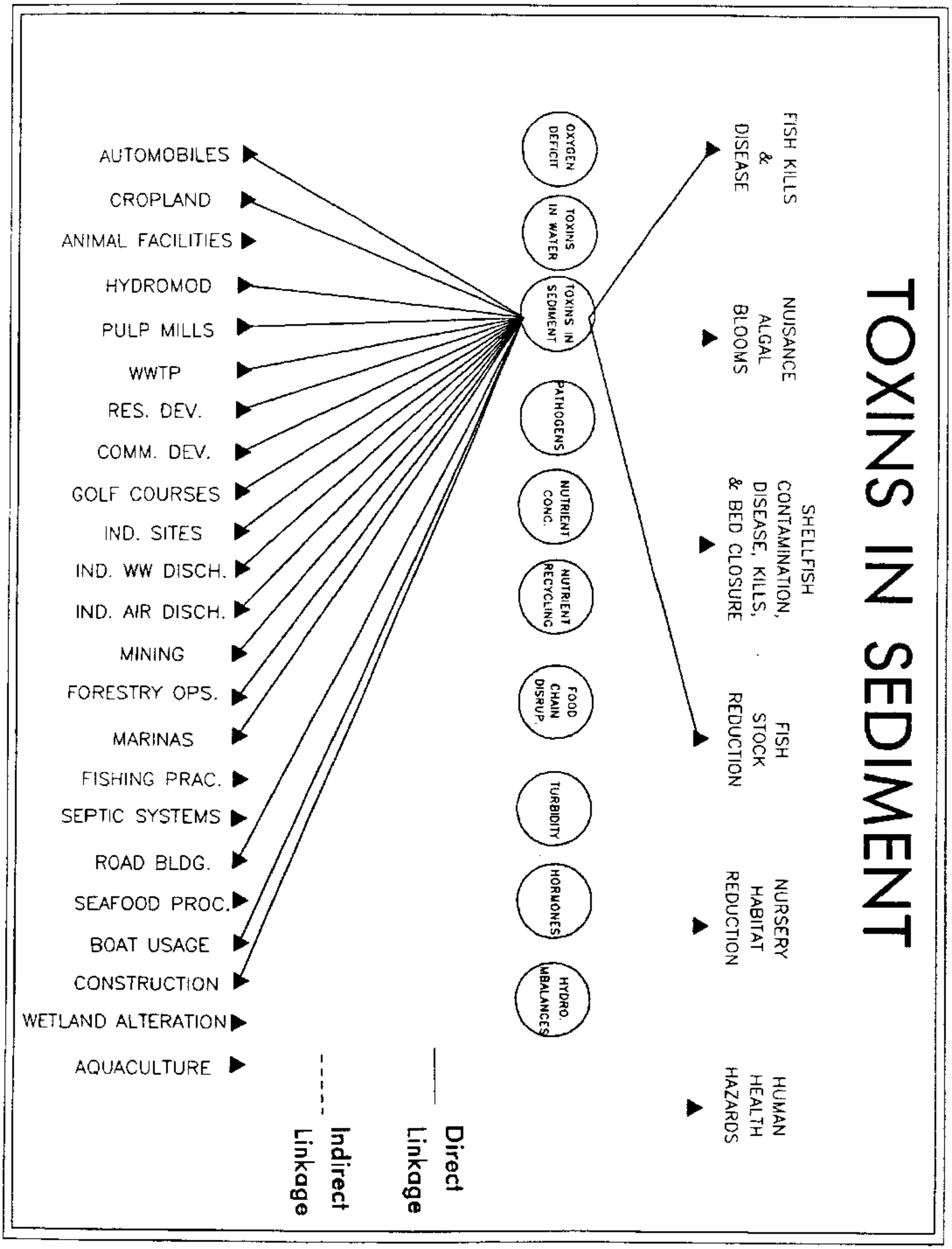
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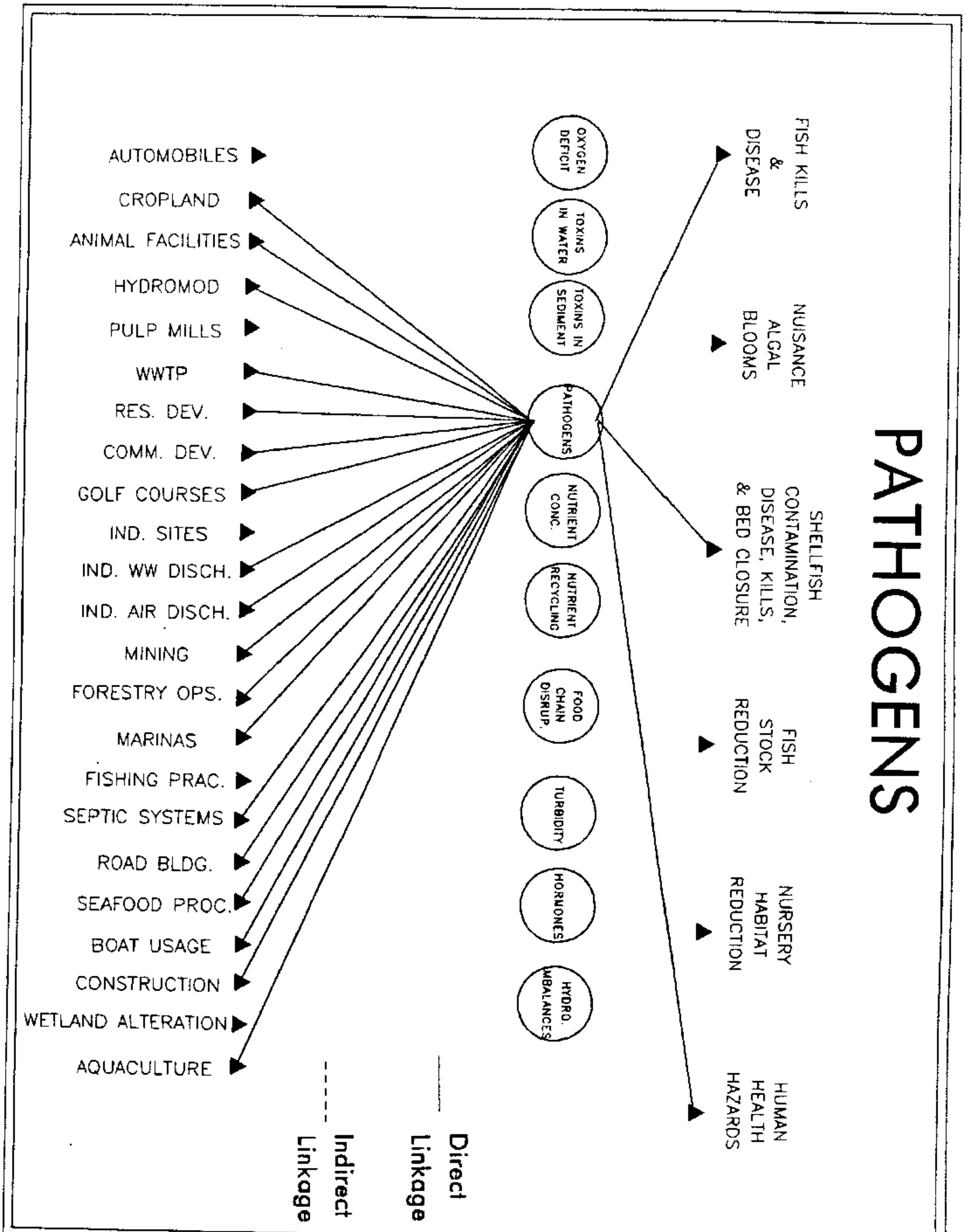
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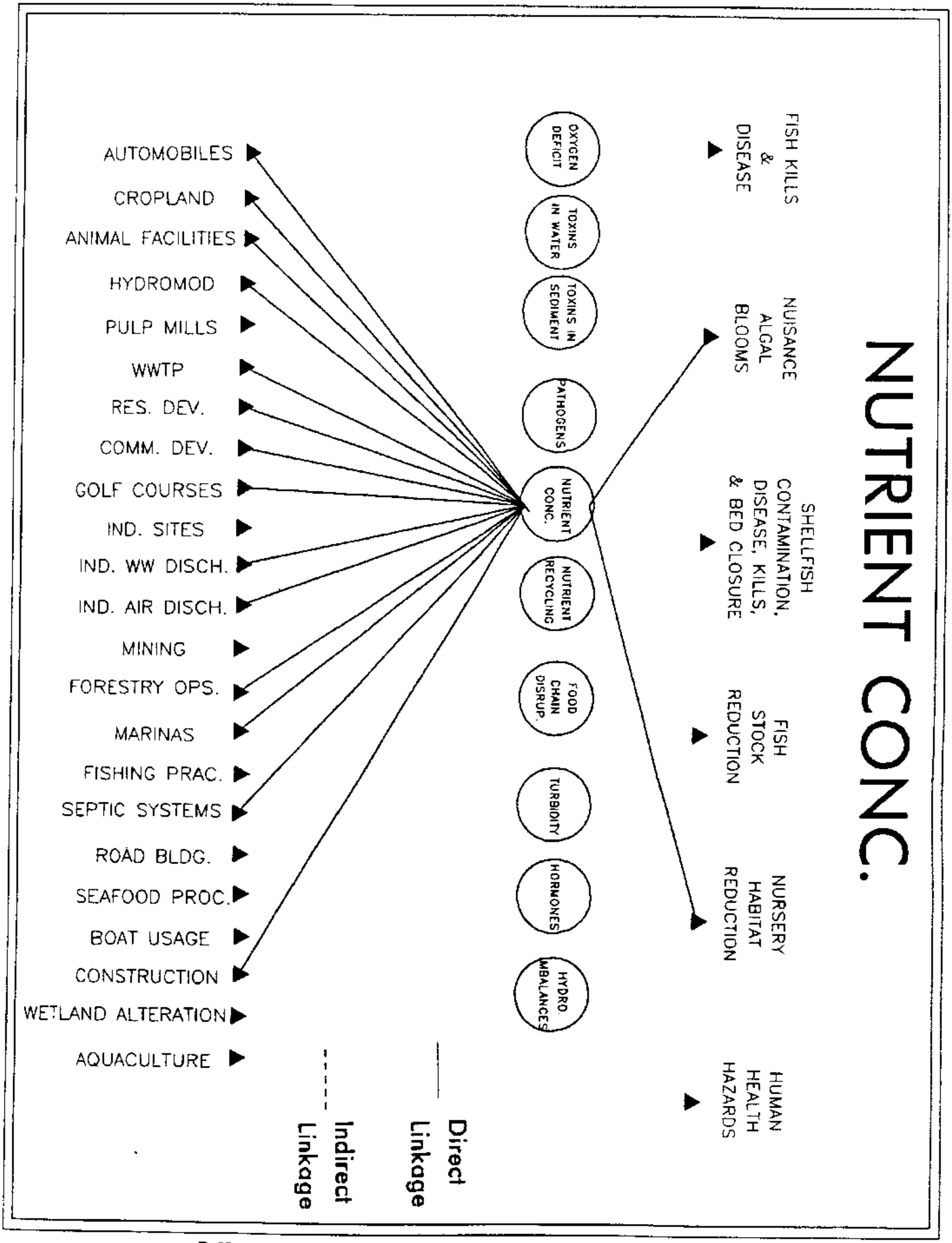
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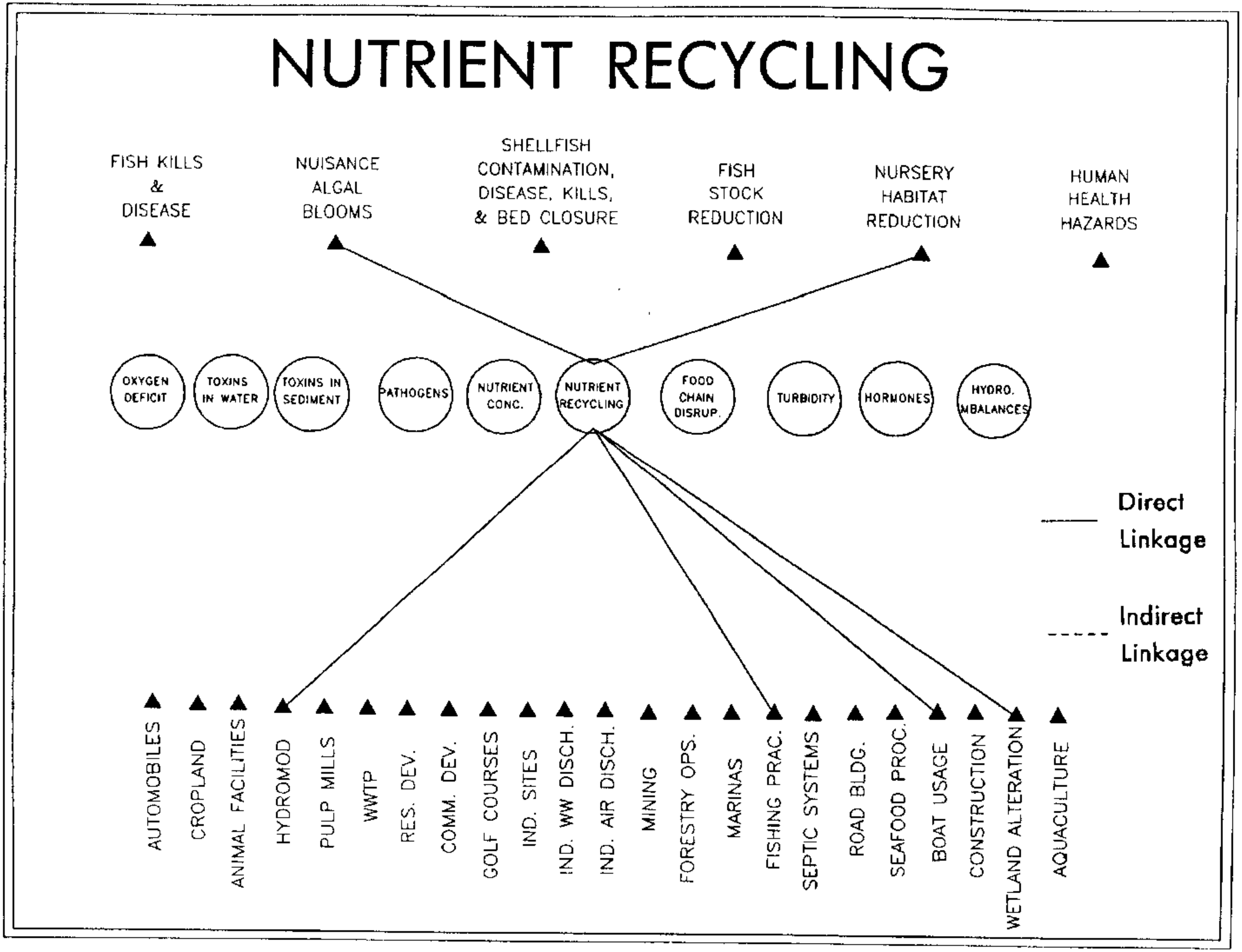
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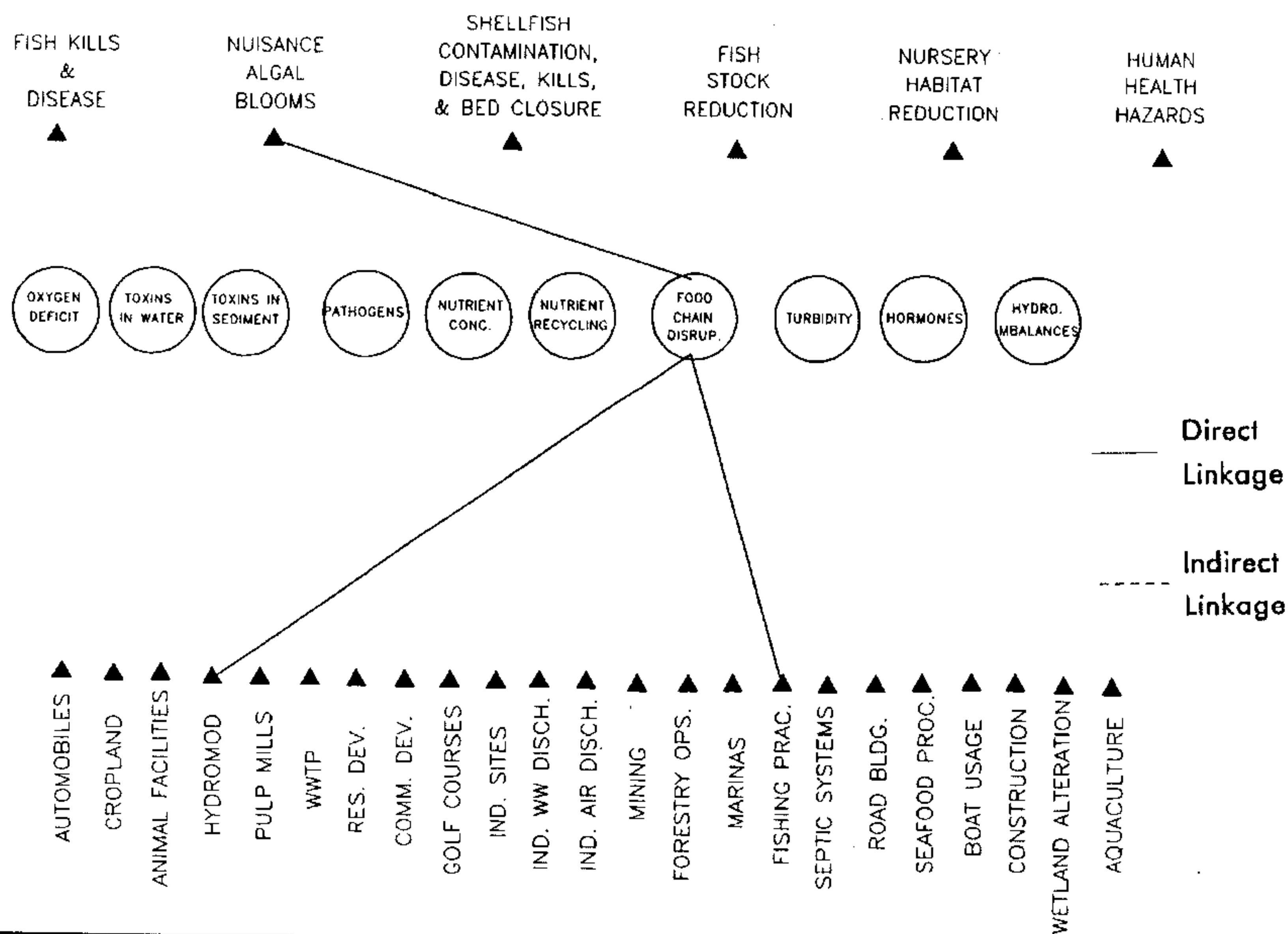

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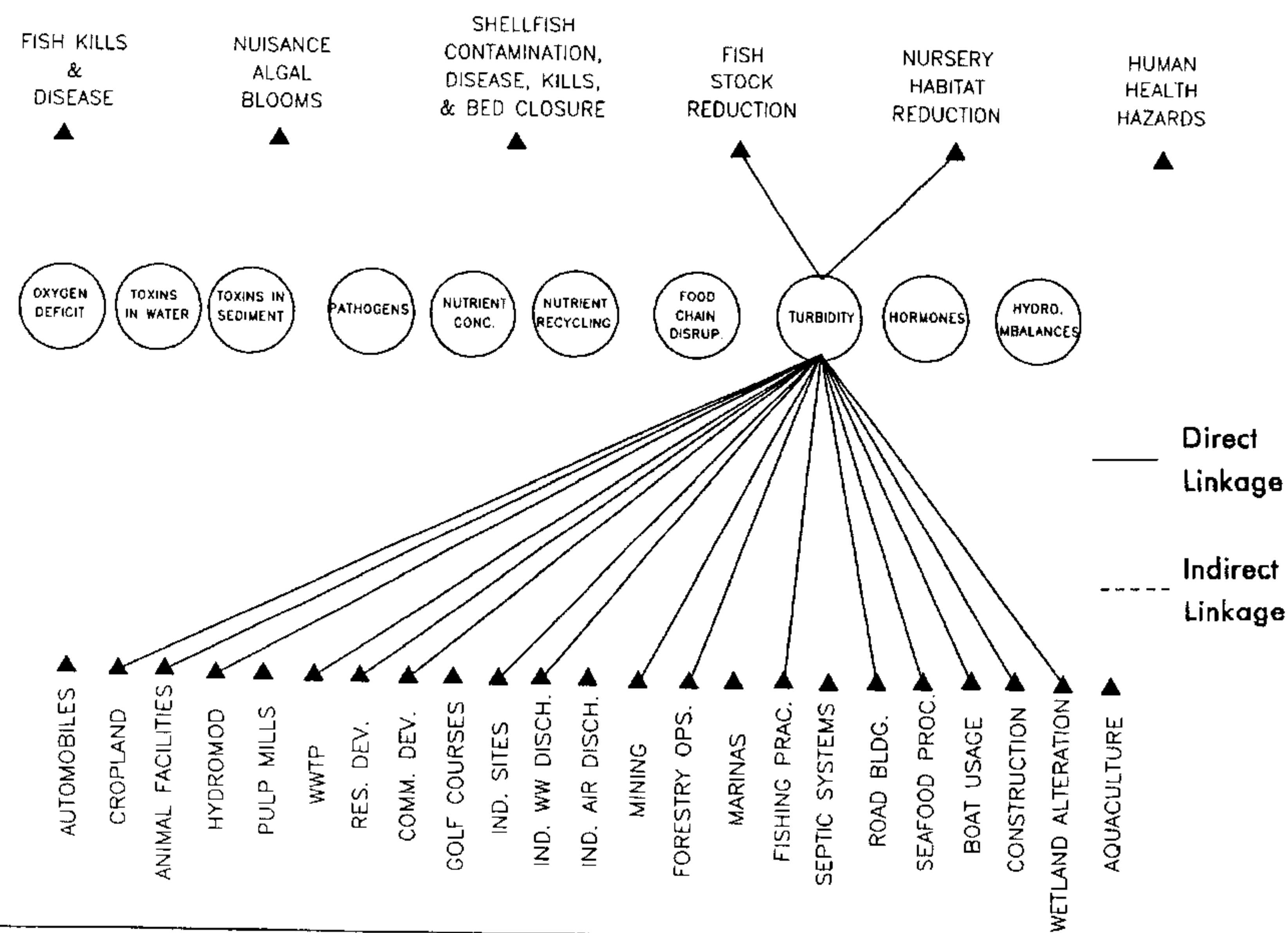
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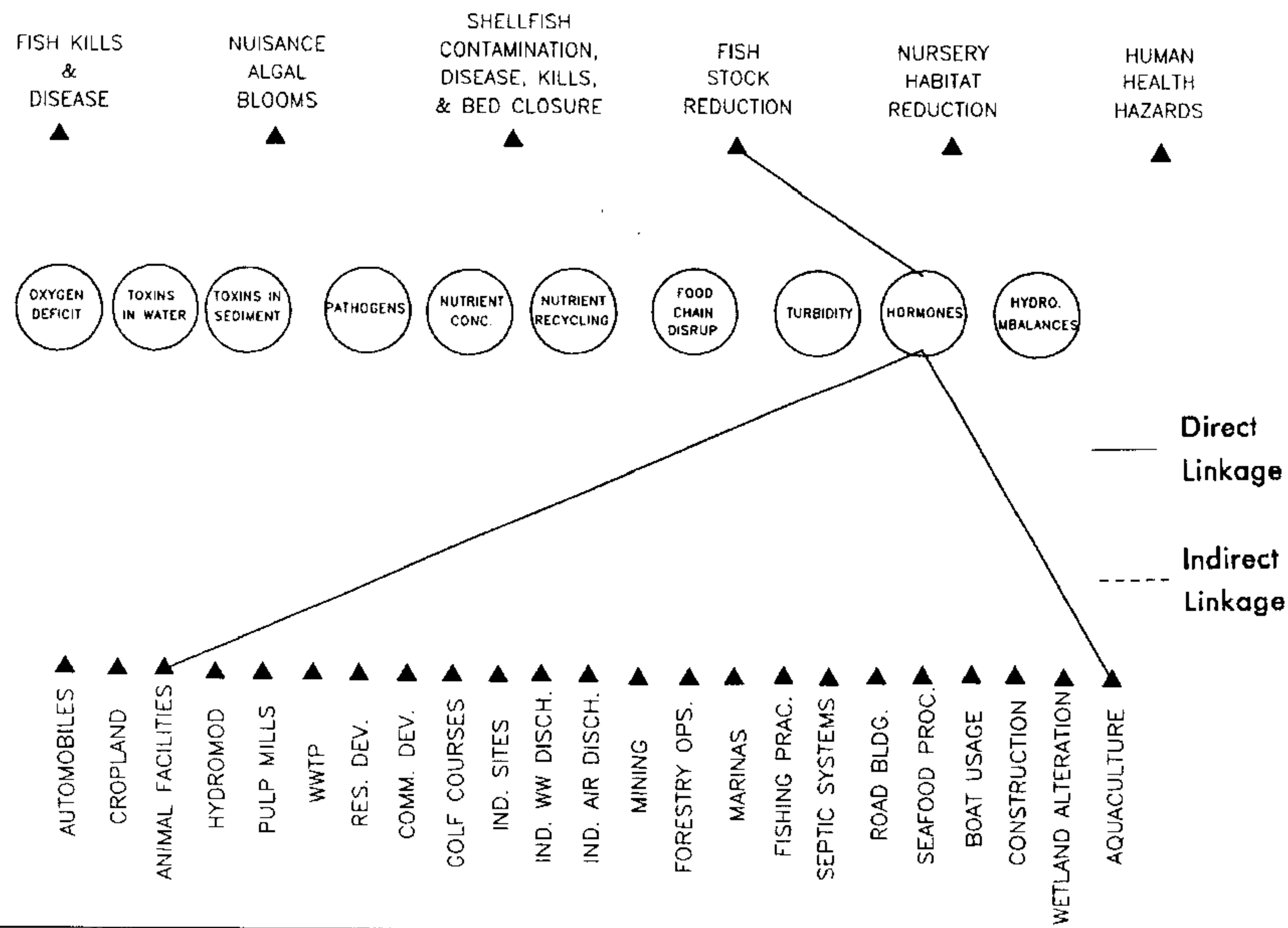
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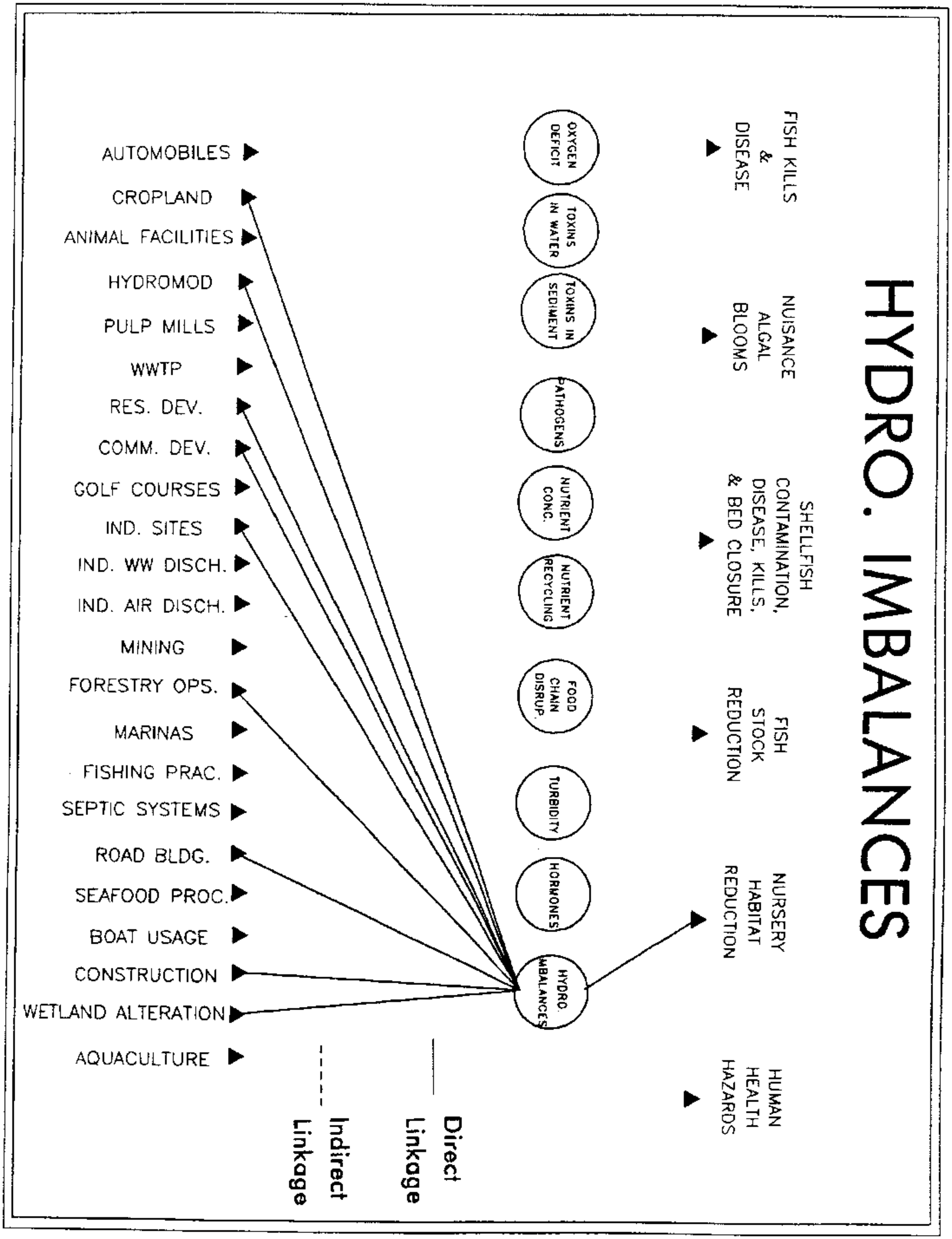
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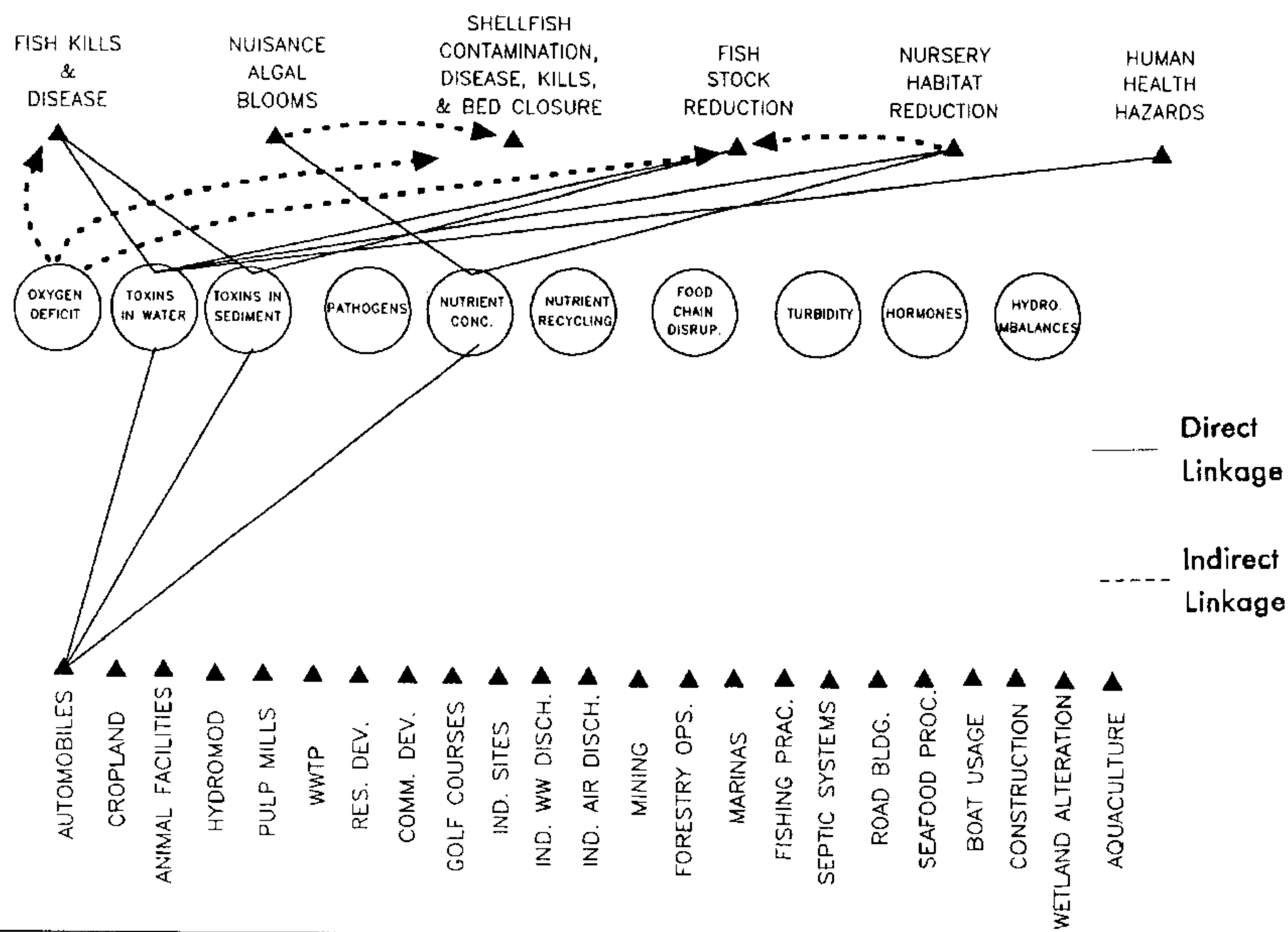

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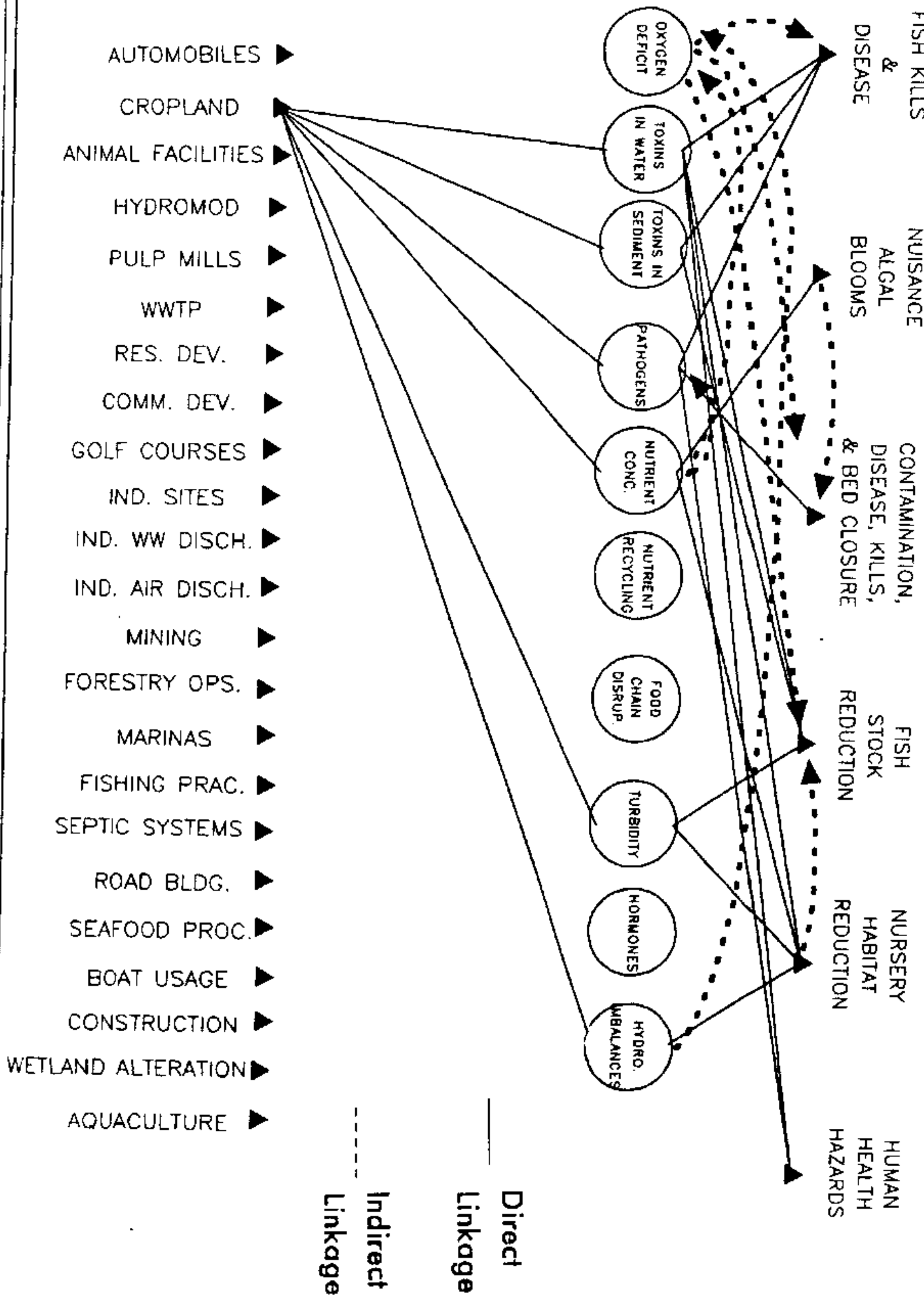
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SEPTIC SYSTEMS
ROAD BLDG.
SEAFOOD PROC.
BOAT USAGE
CONSTRUCTION
WETLAND ALTERATION
AQUACULTURE
OXYGEN DEFICIT
TOXINS IN WATER
TOXINS IN SEDIMENT
PATHOGENS
NUTRIENT CONC.
NUTRIENT RECYCLING
FOOD CHAIN DISRUP.
TURBIDITY
HORMONES
HYDRO. IMBALANCES
FISH KILLS & DISEASE
NUISANCE ALGAL BLOOMS
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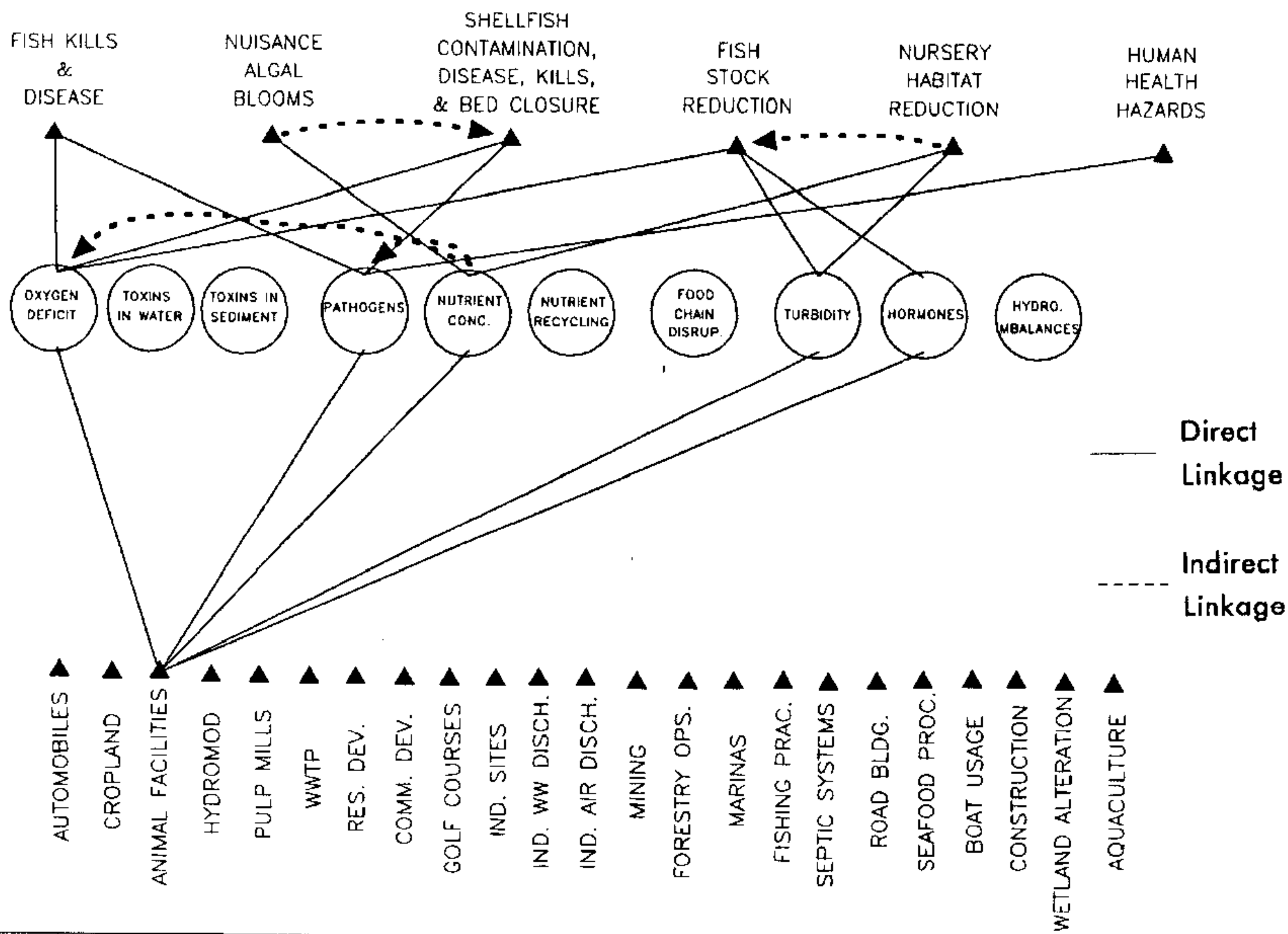

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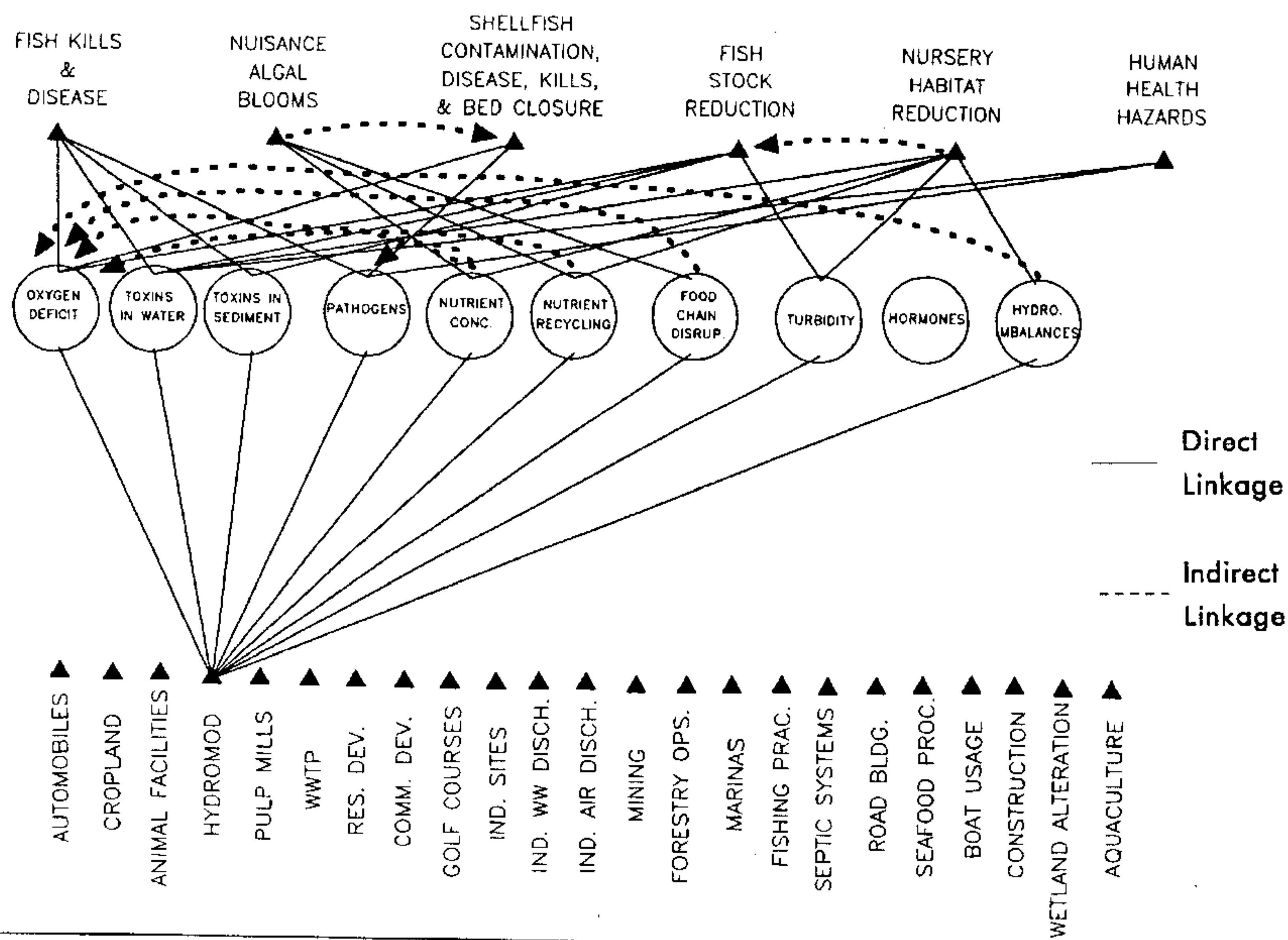

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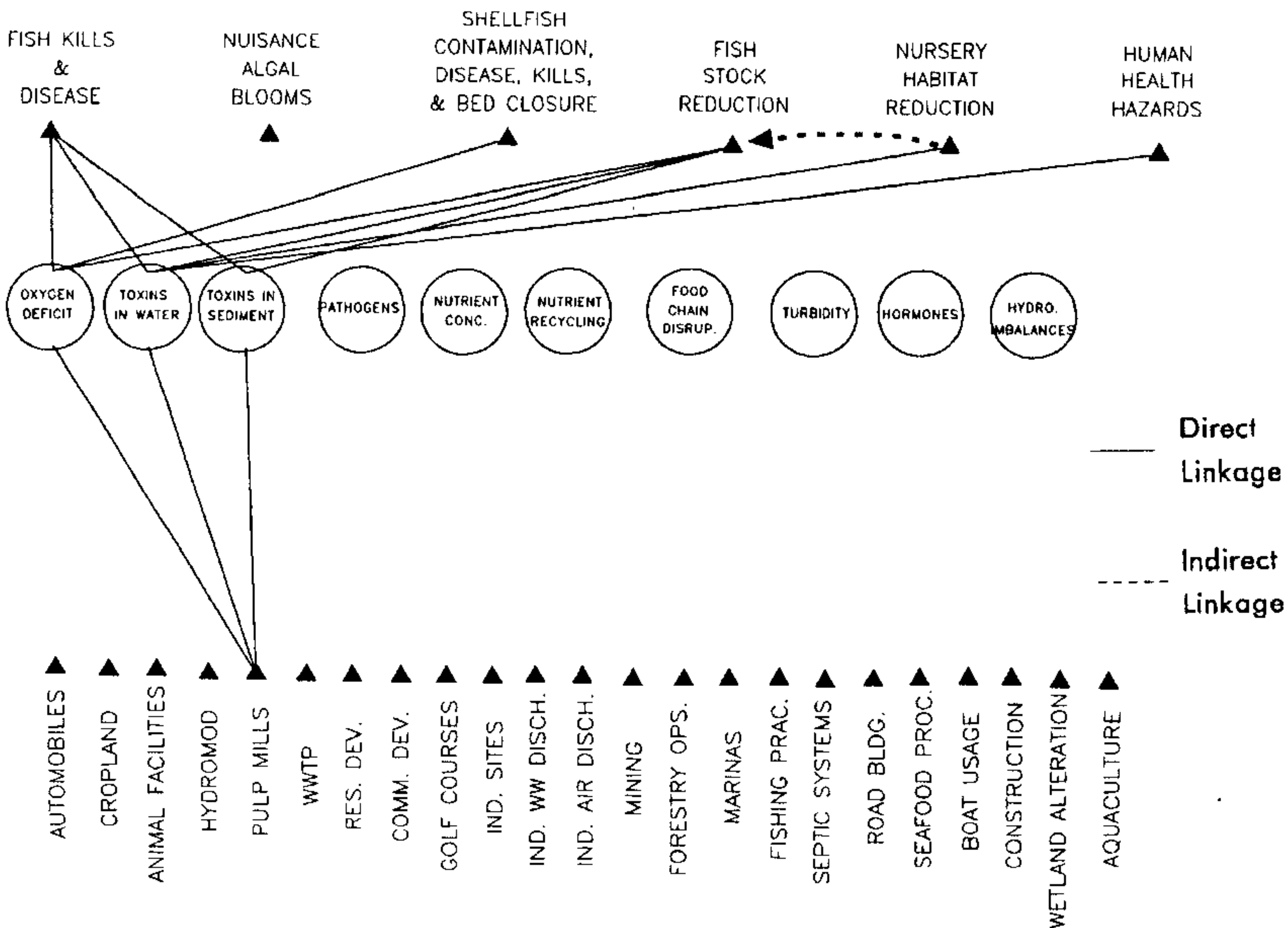
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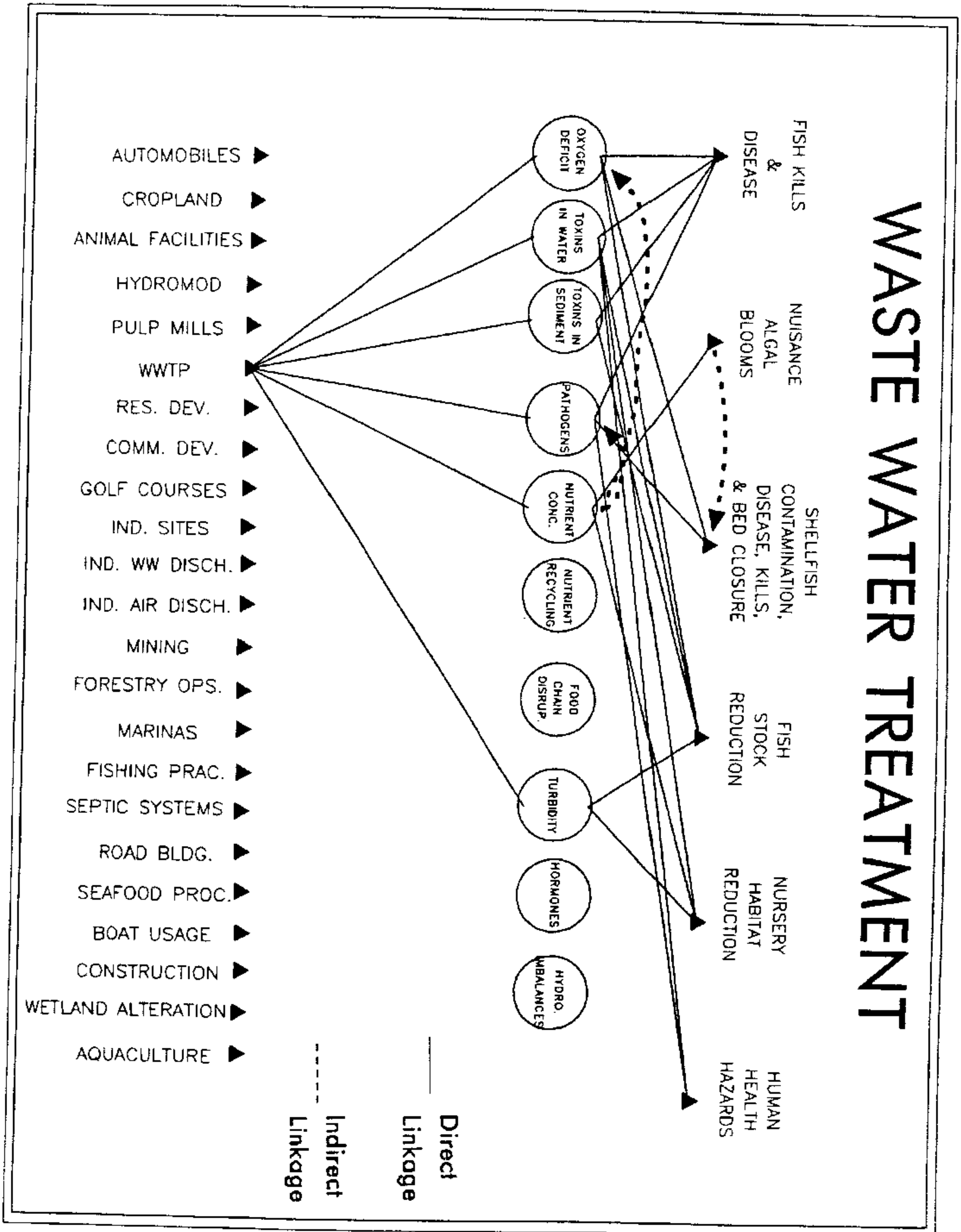
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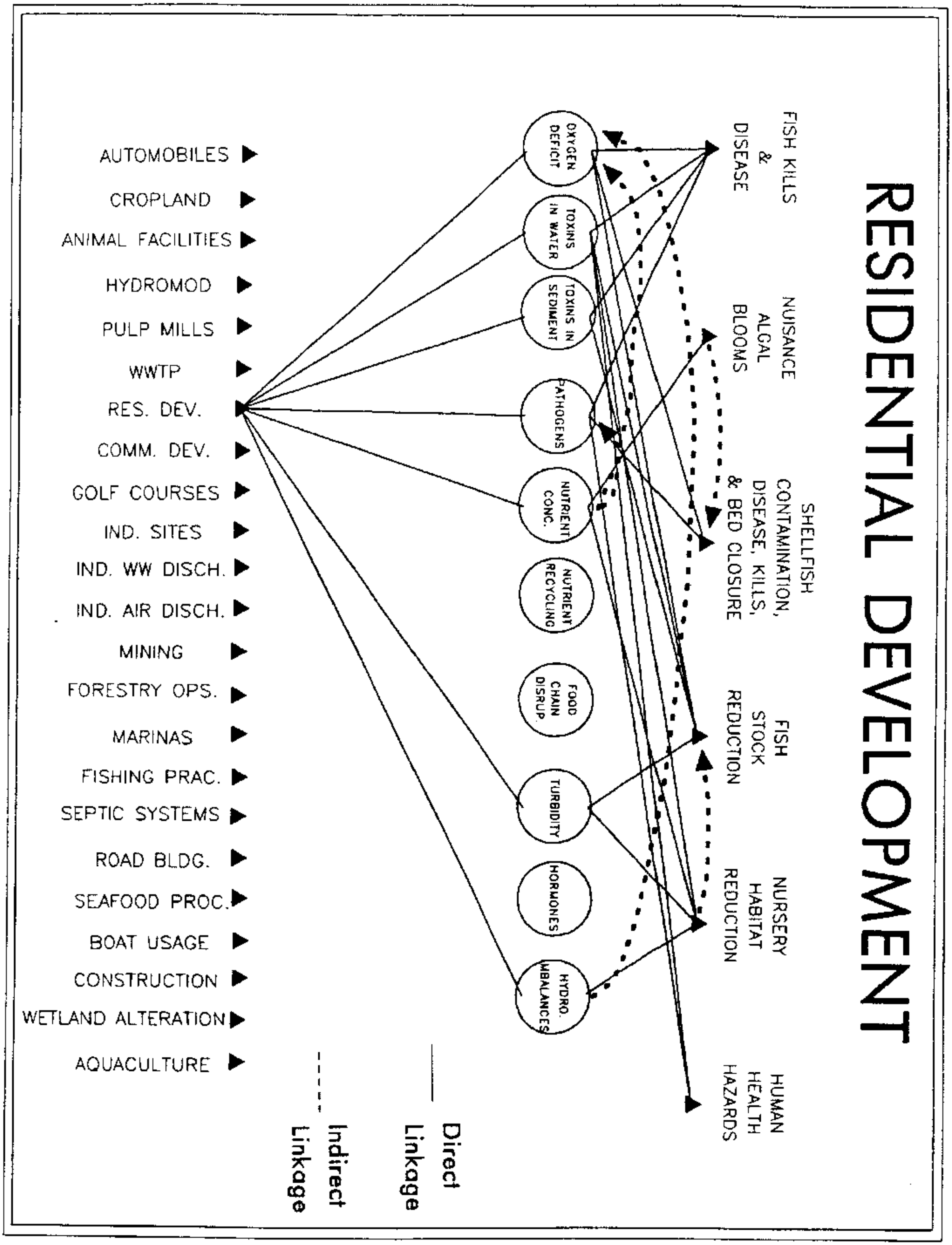
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SEPTIC SYSTEMS
ROAD BLDG.
SEAFOOD PROC.
BOAT USAGE
CONSTRUCTION
WETLAND ALTERATION
AQUACULTURE
OXYGEN DEFICIT
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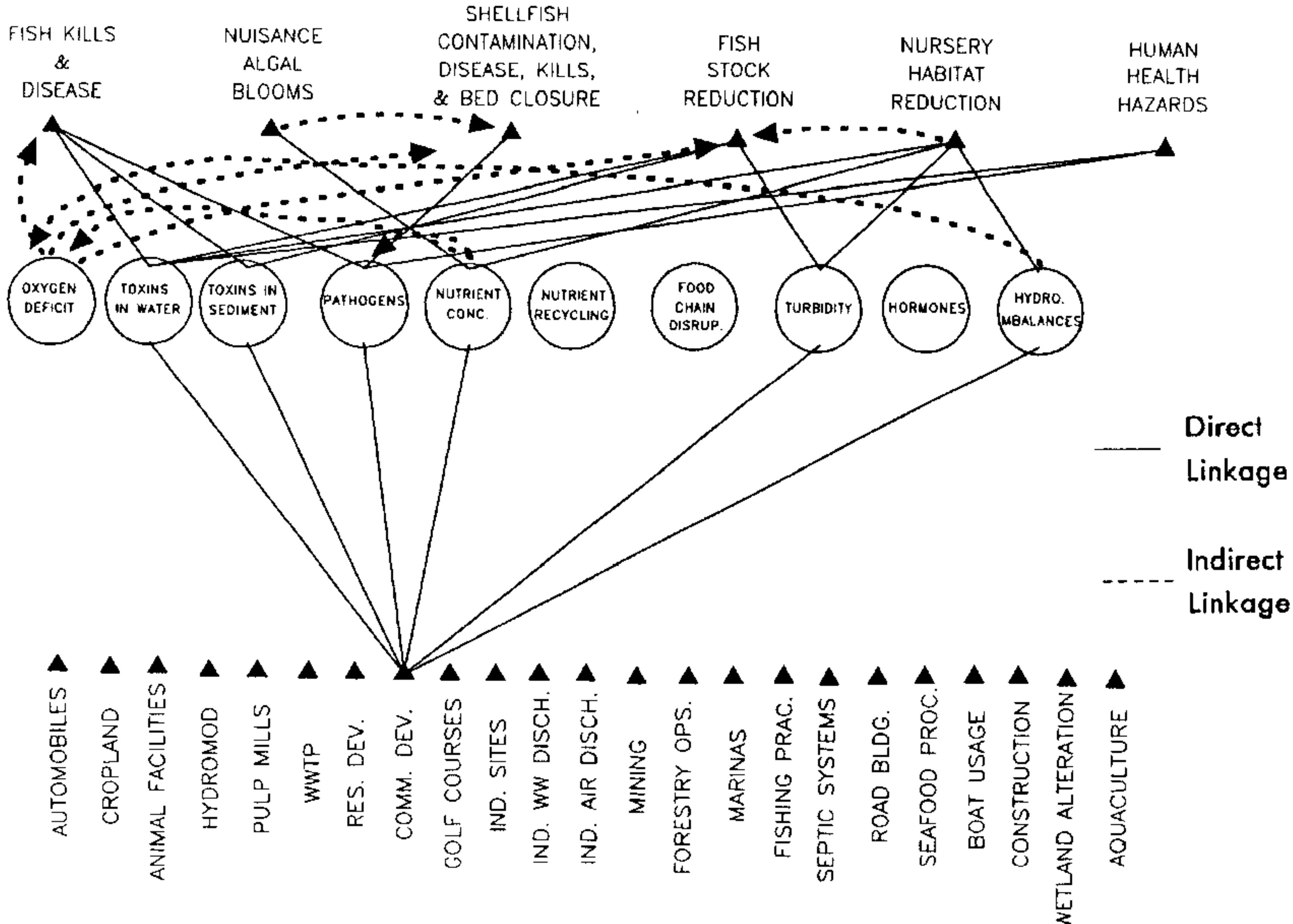
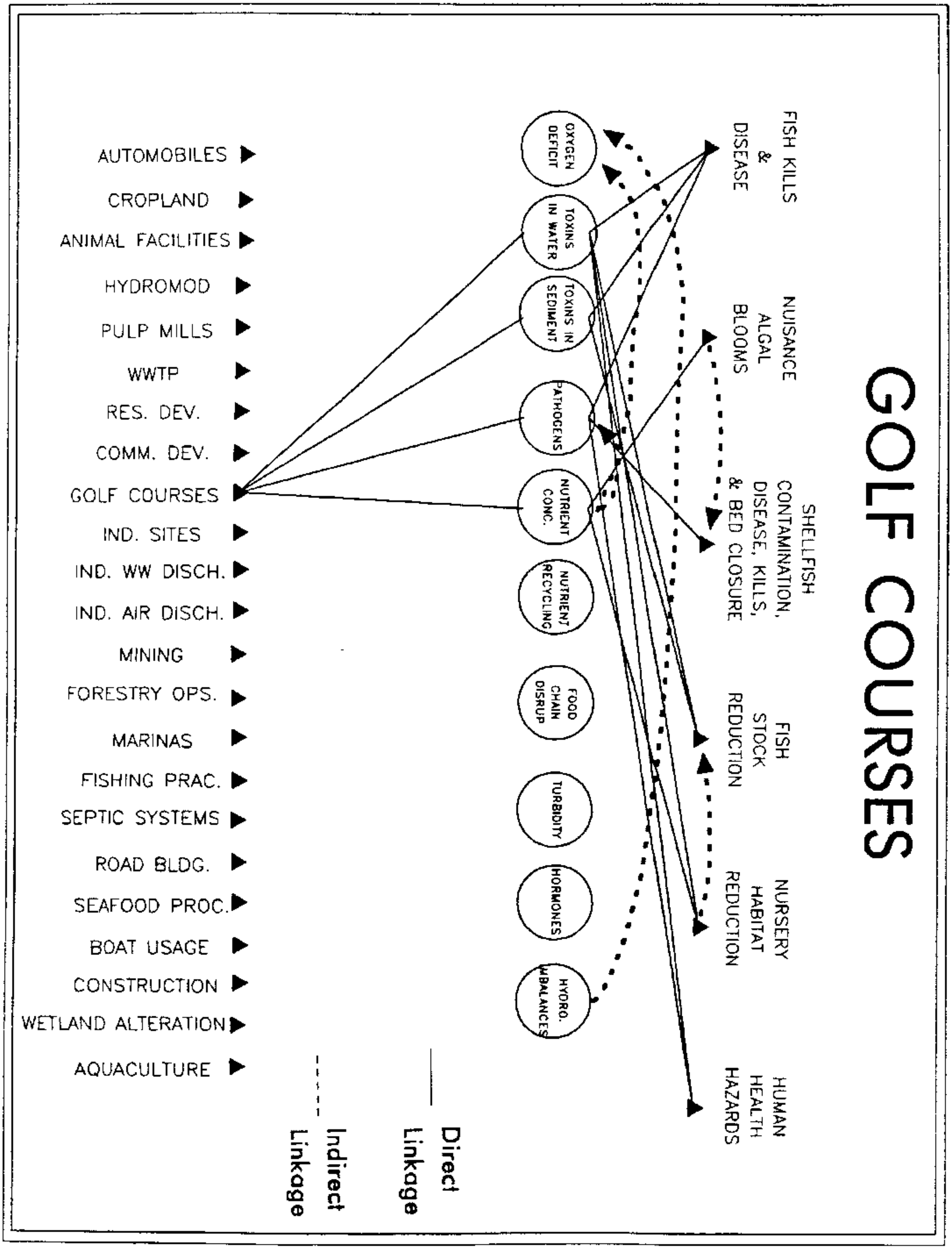
FISH KILLS & DISEASE
NUISANCE ALGAL BLOOMS
SHELLFISH CONTAMINATION, DISEASE, KILLS, & BED CLOSURE
FISH STOCK REDUCTION
NURSERY HABITAT REDUCTION
HUMAN HEALTH HAZARDS
Direct Linkage
Indirect Linkage

COMMERCIAL DEVELOPMENT

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SEAFOOD PROC.
BOAT USAGE
CONSTRUCTION
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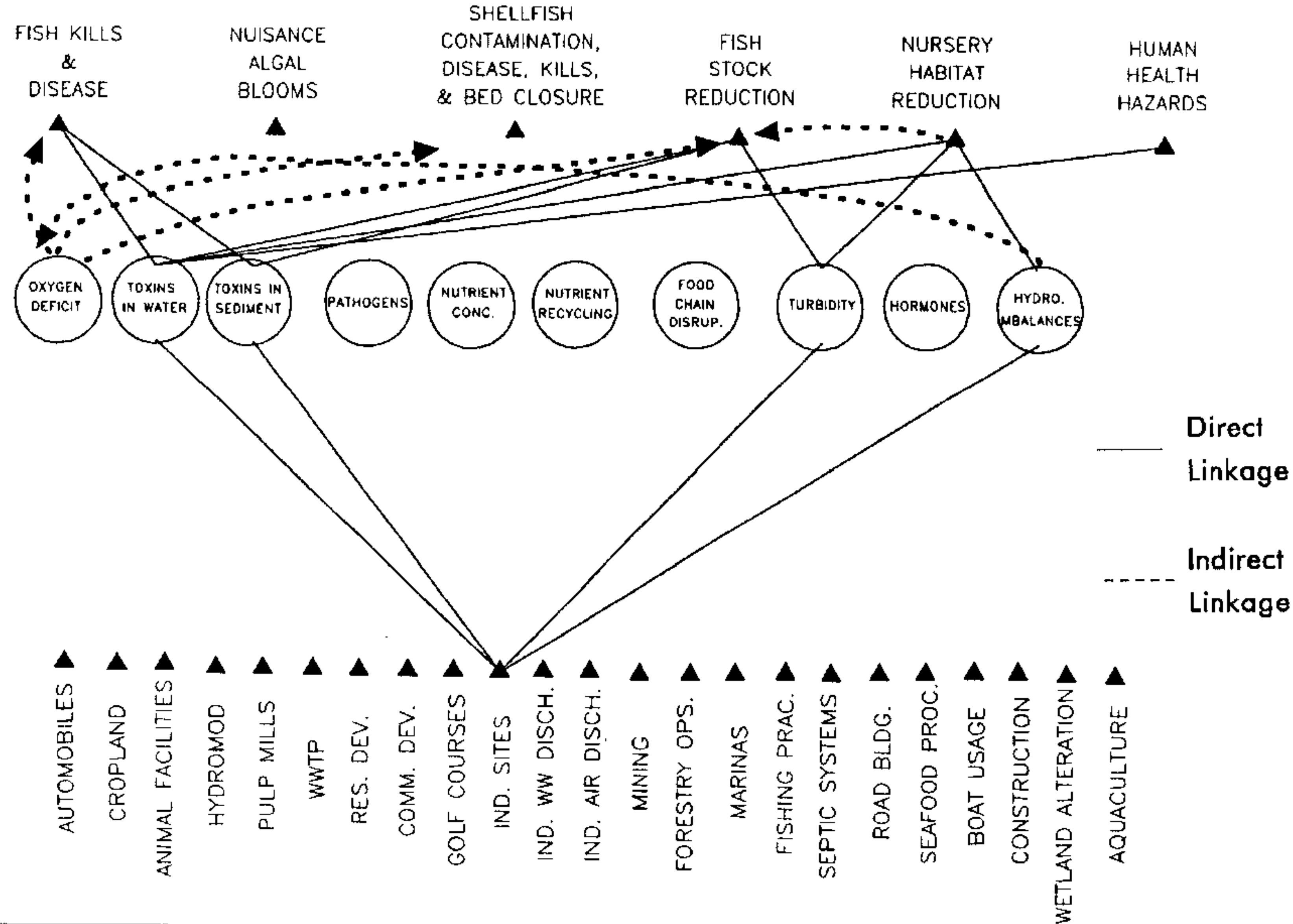
INDUSTRIAL SITES



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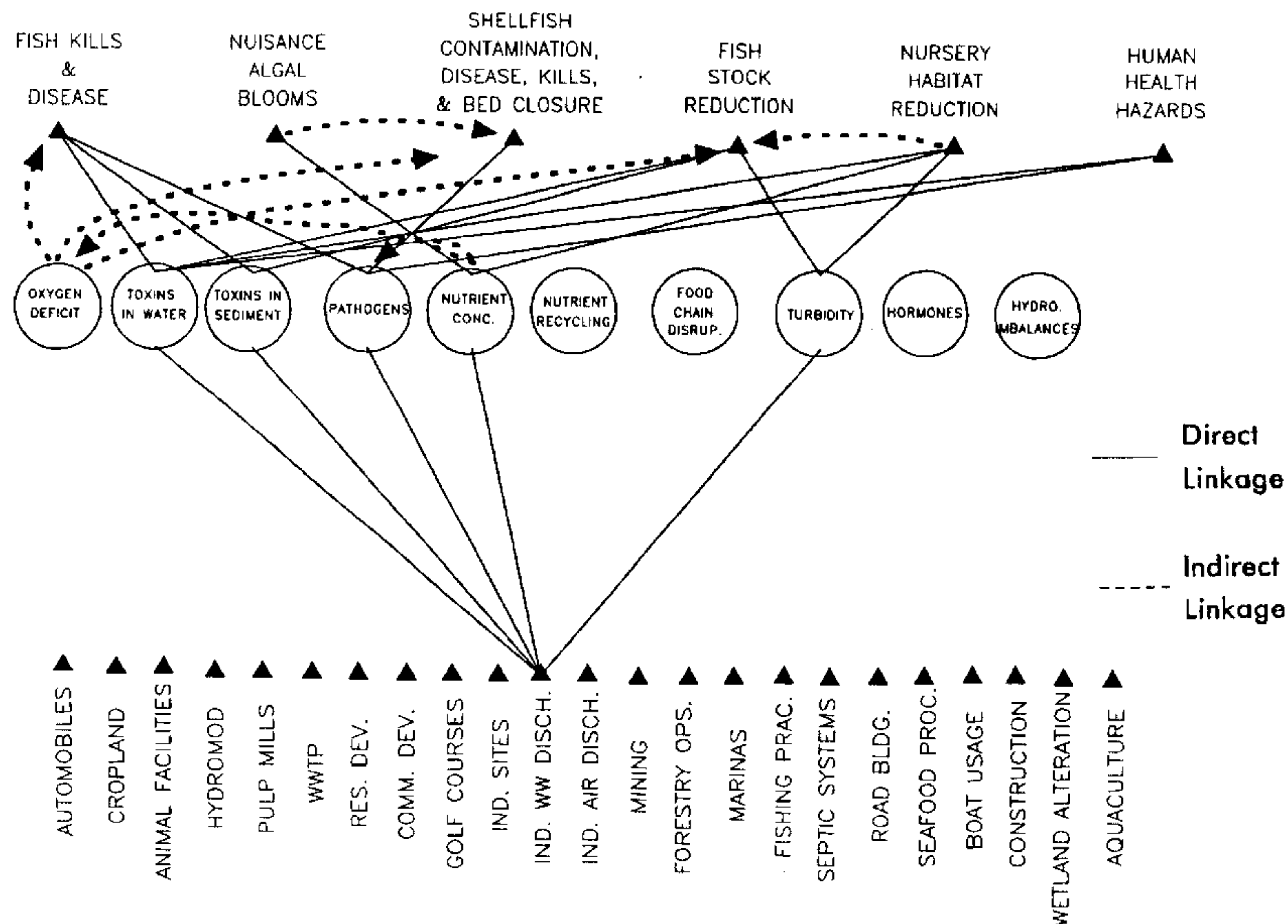

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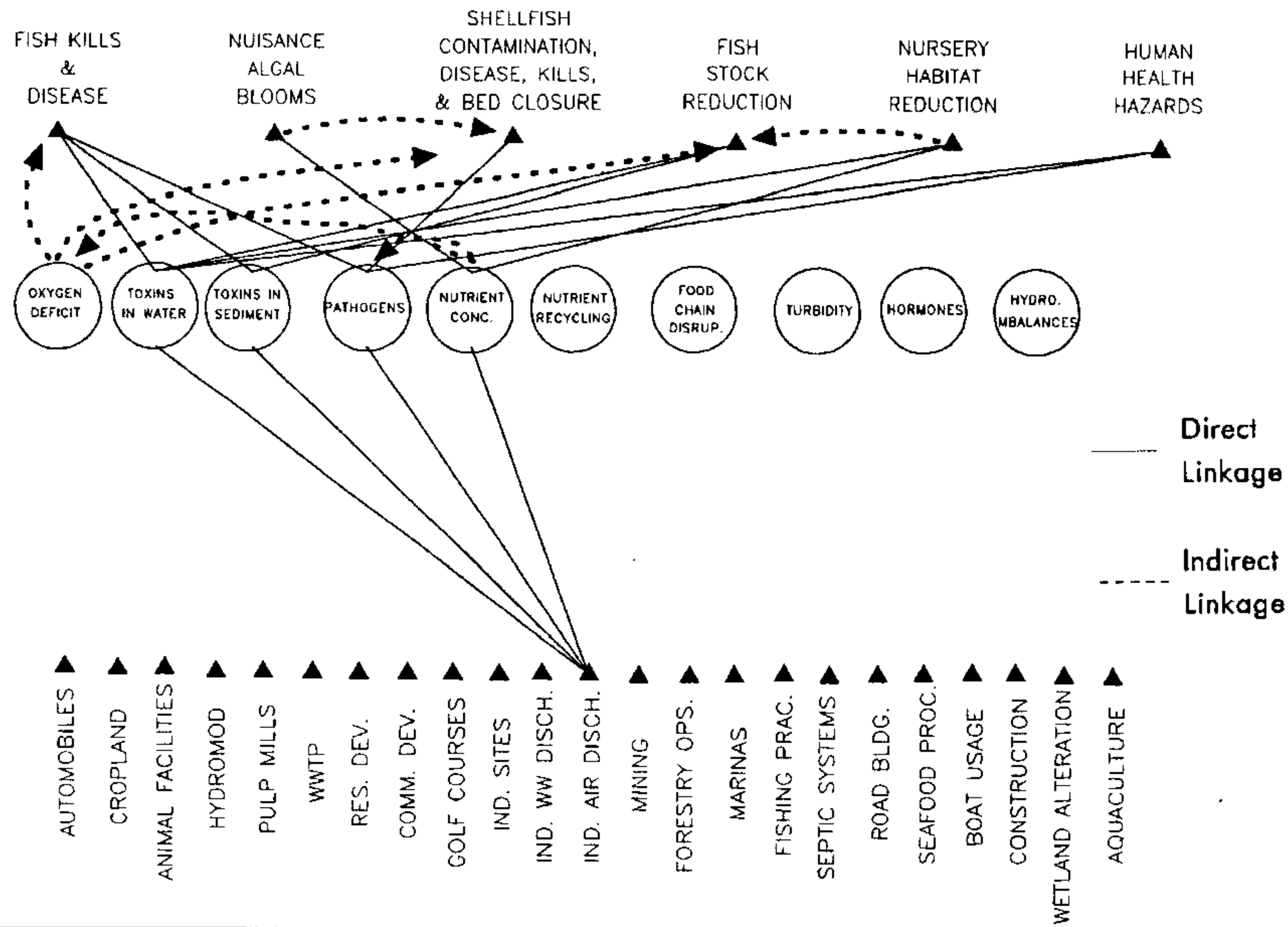

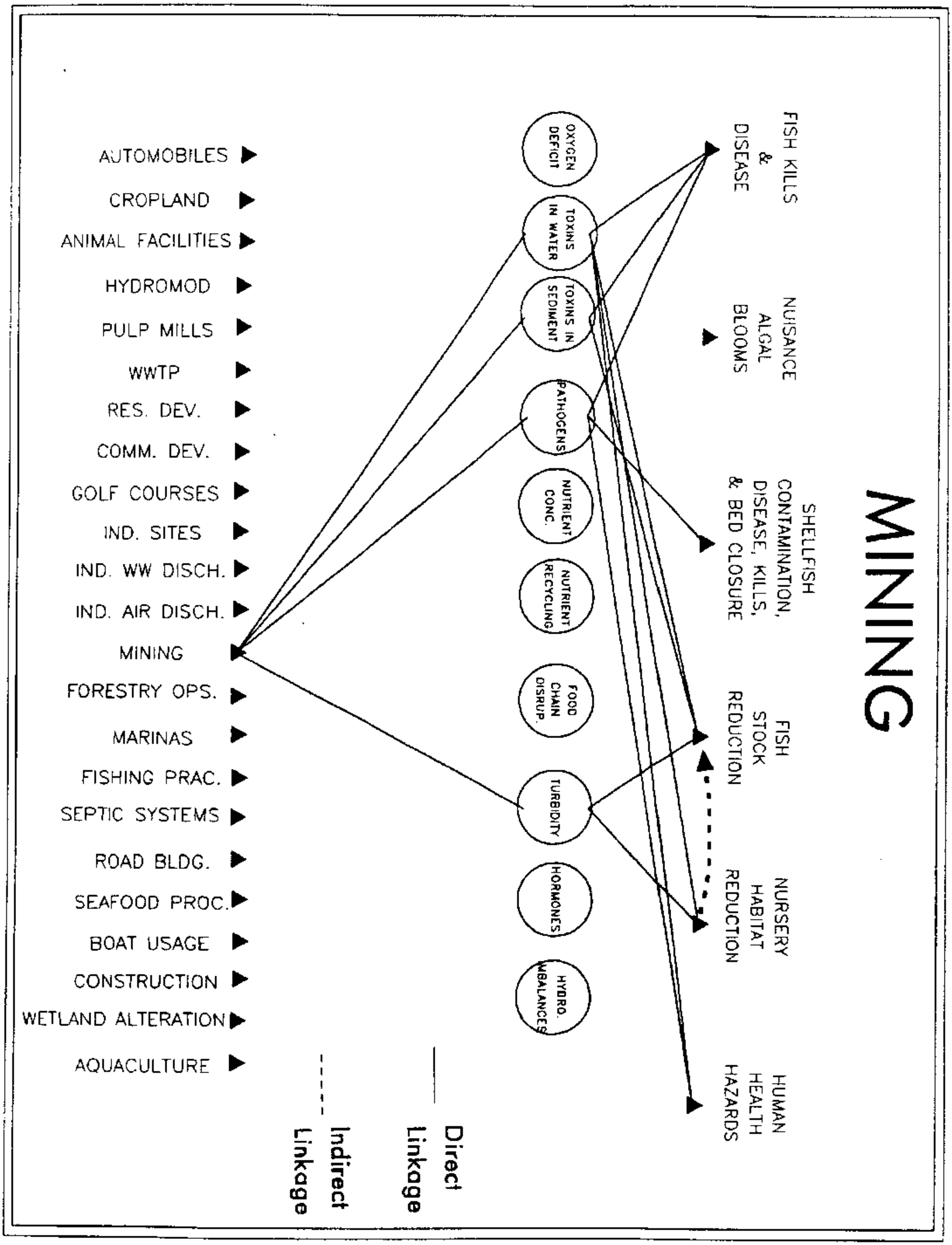
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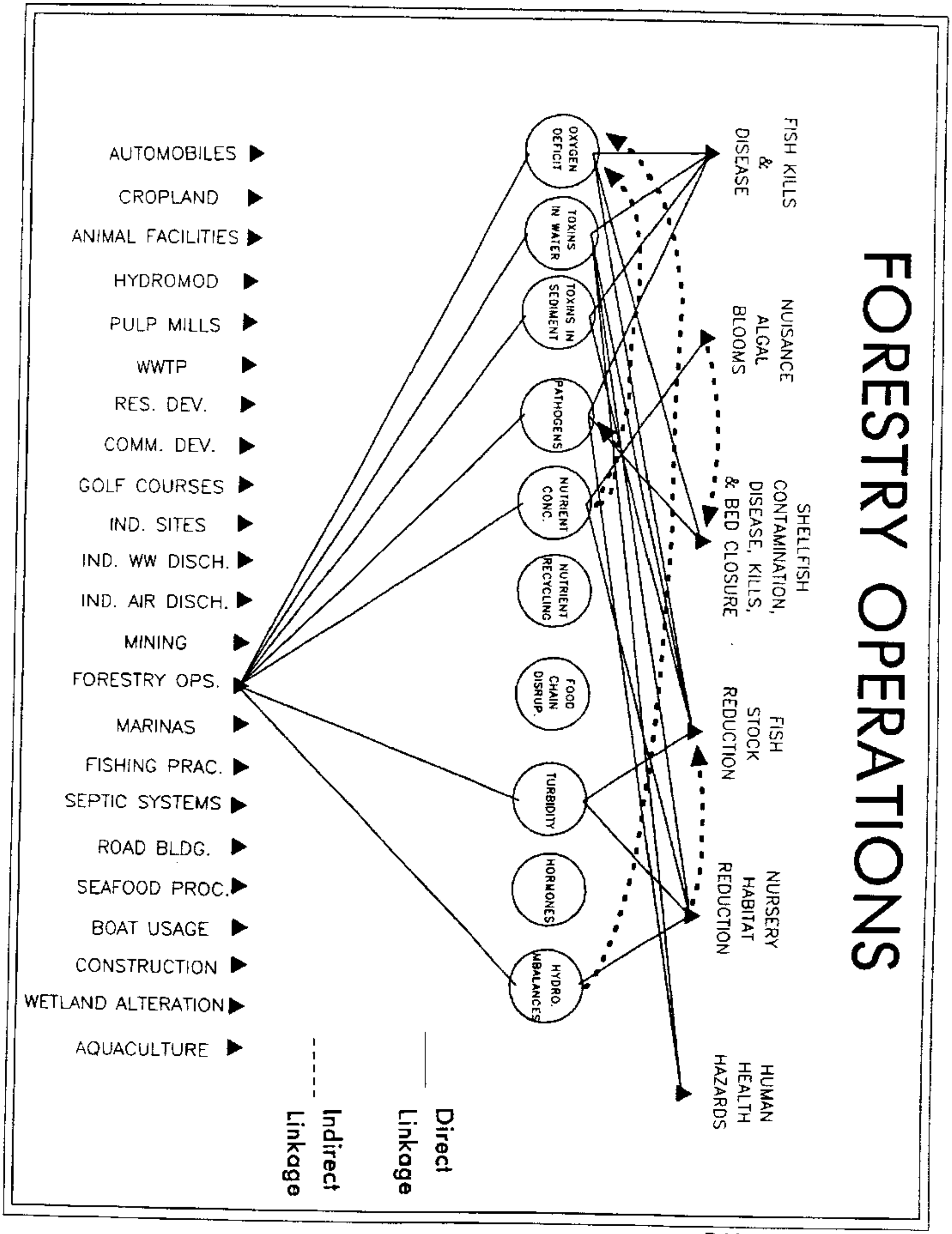
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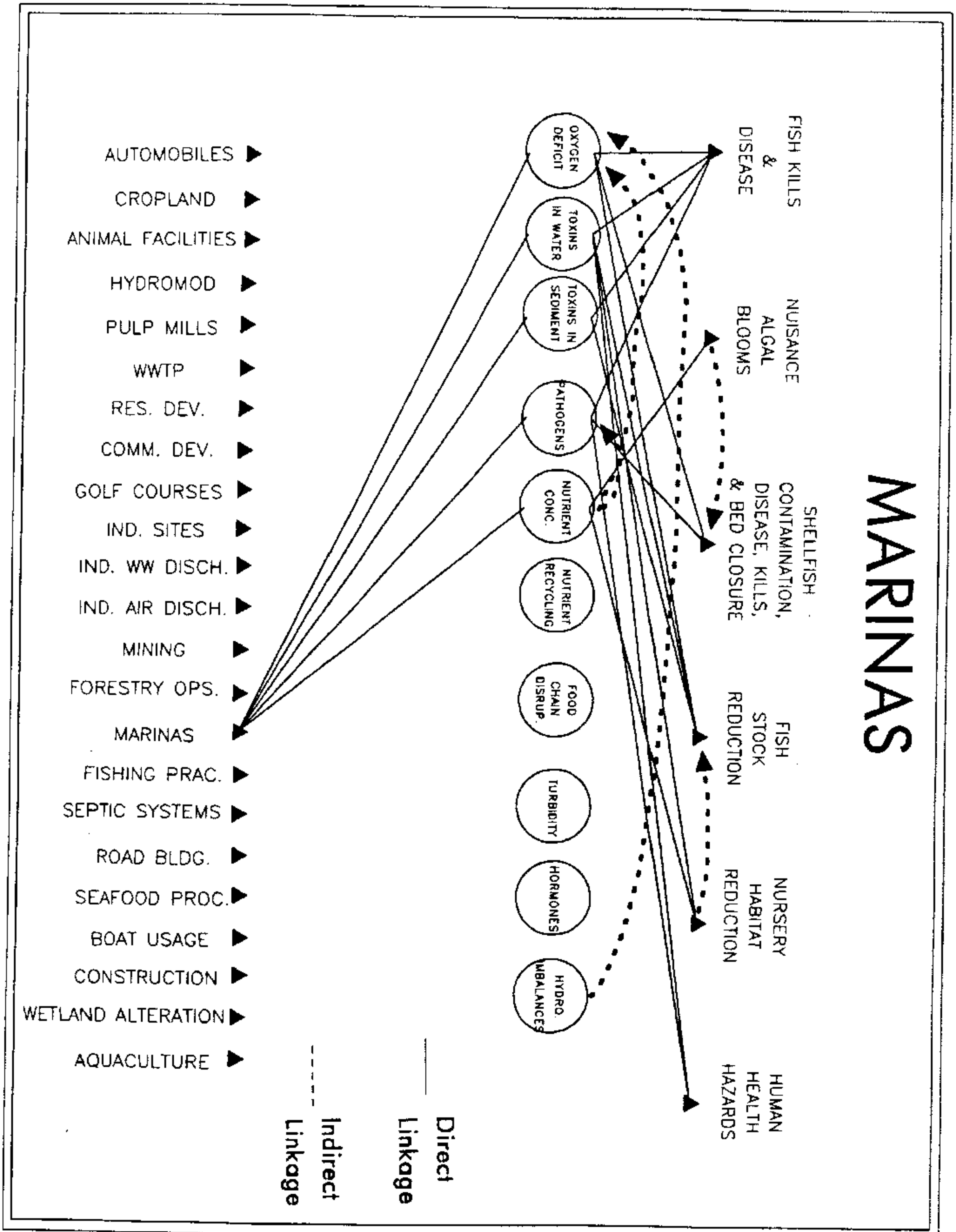
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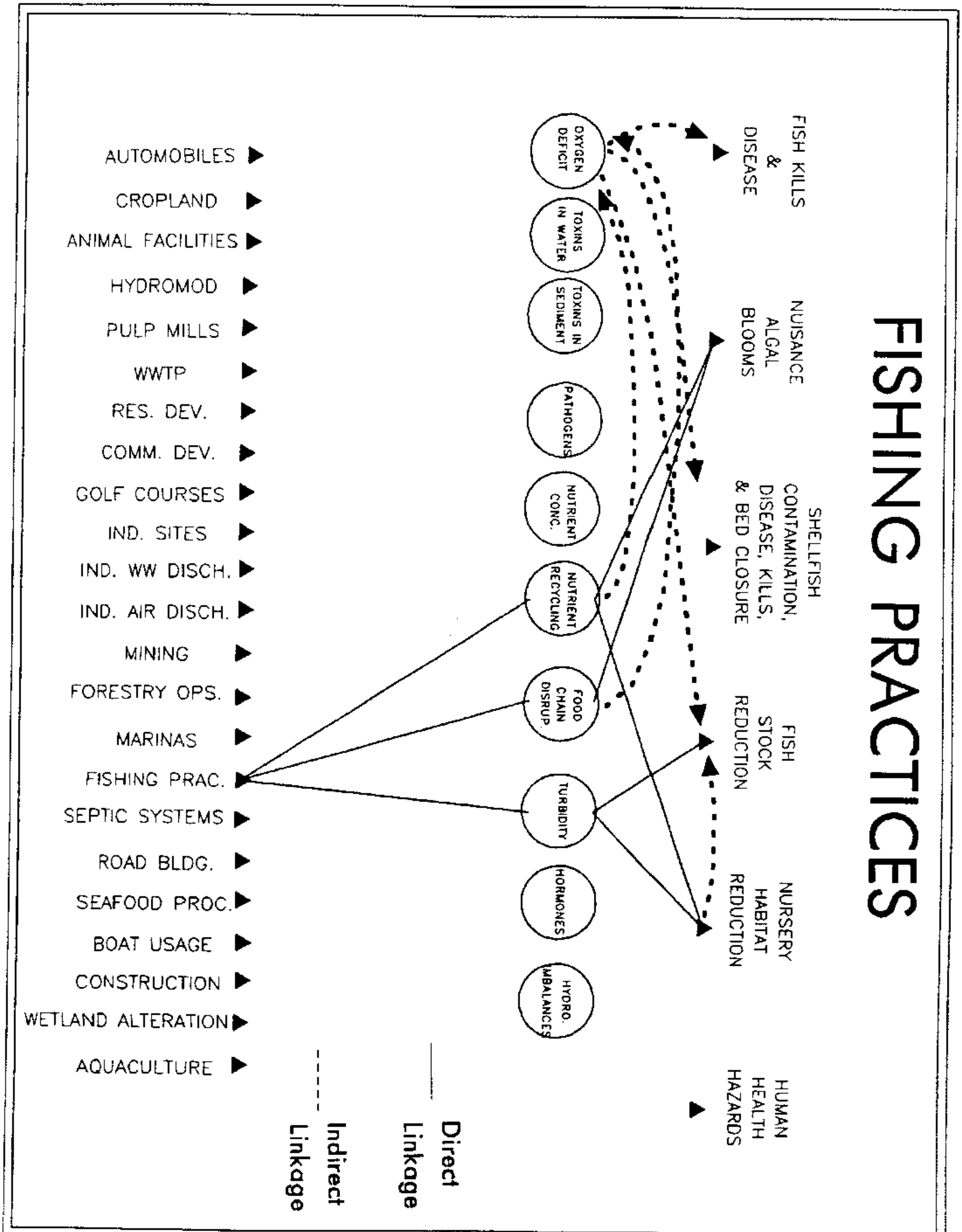
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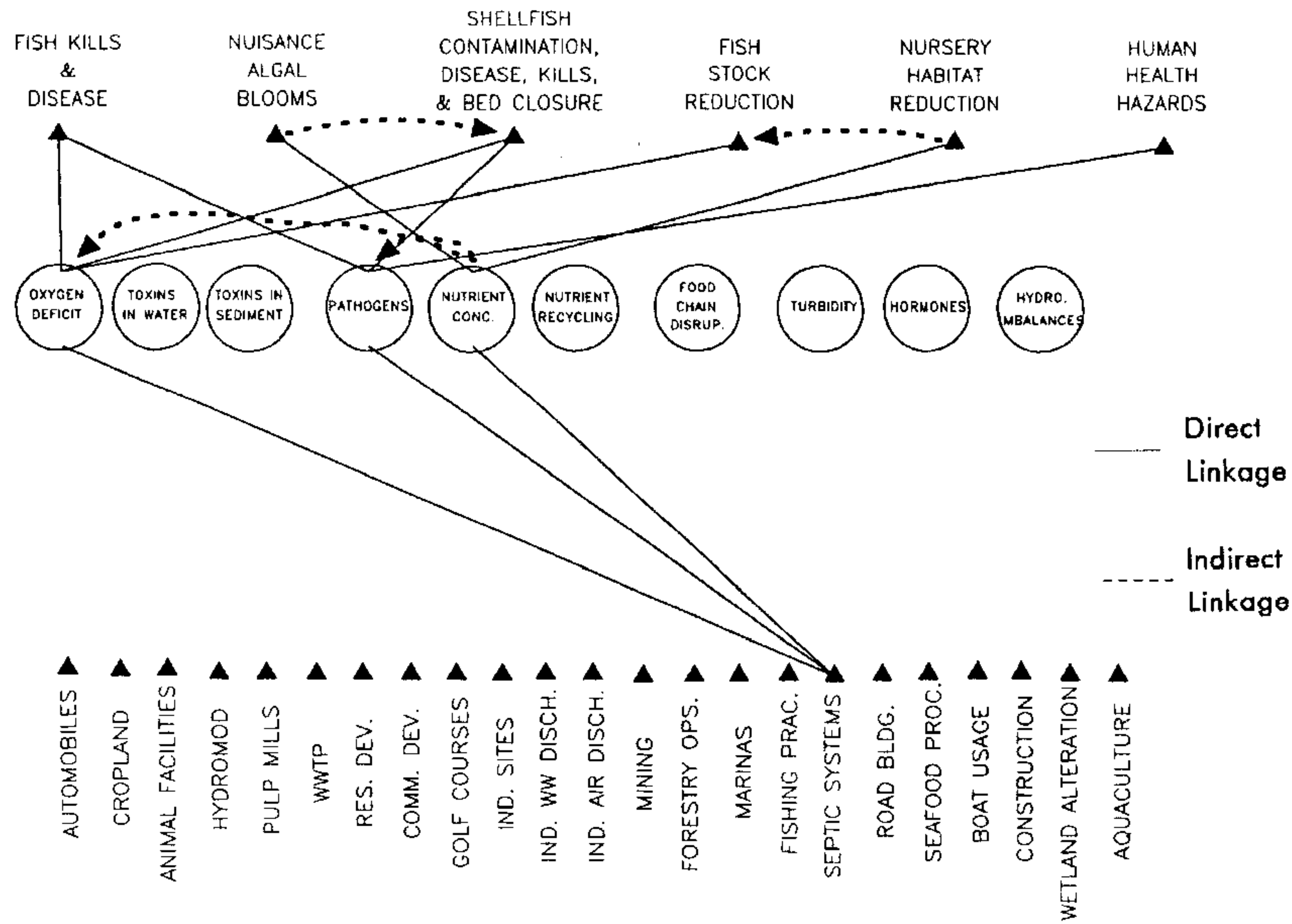

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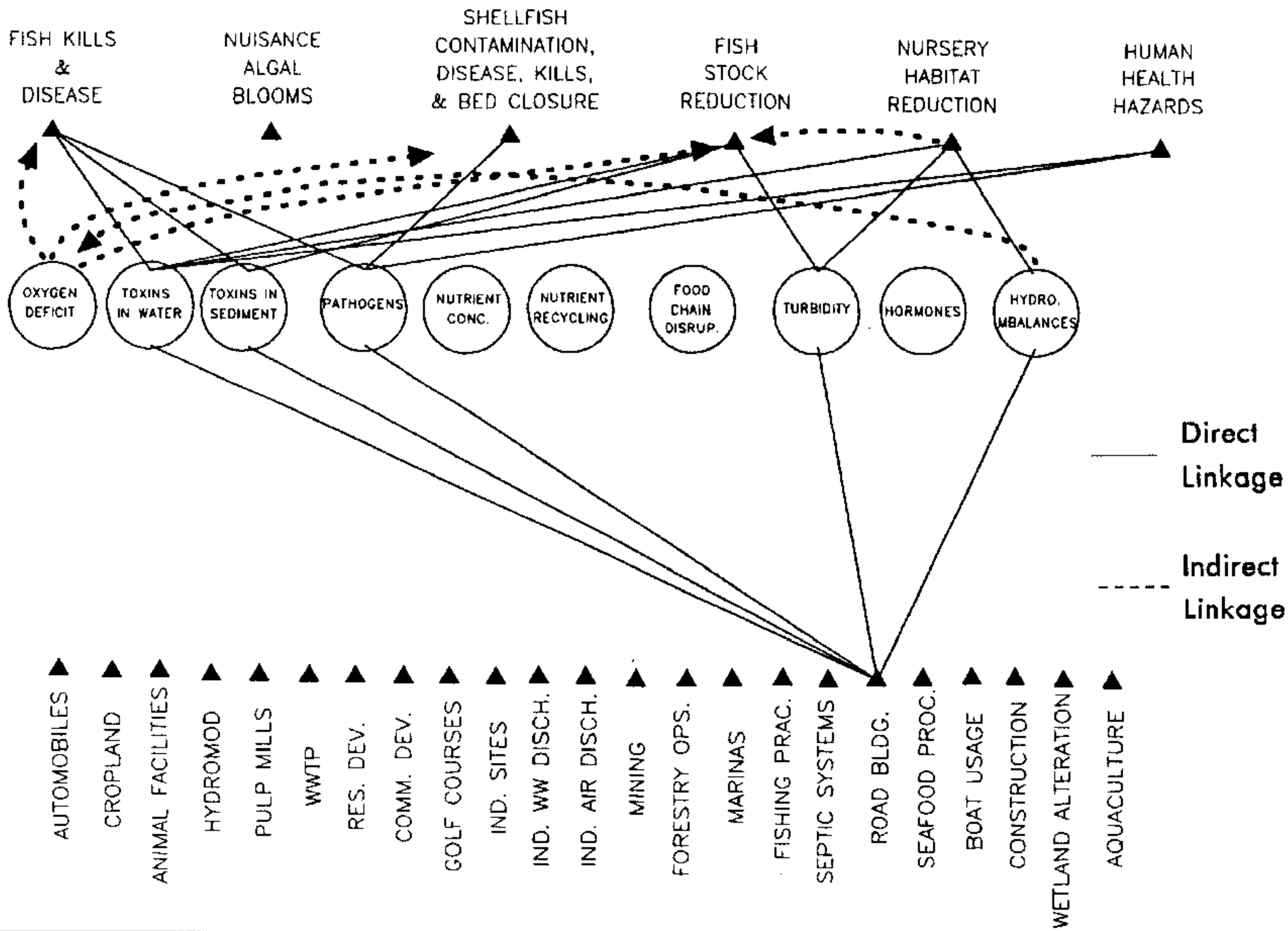

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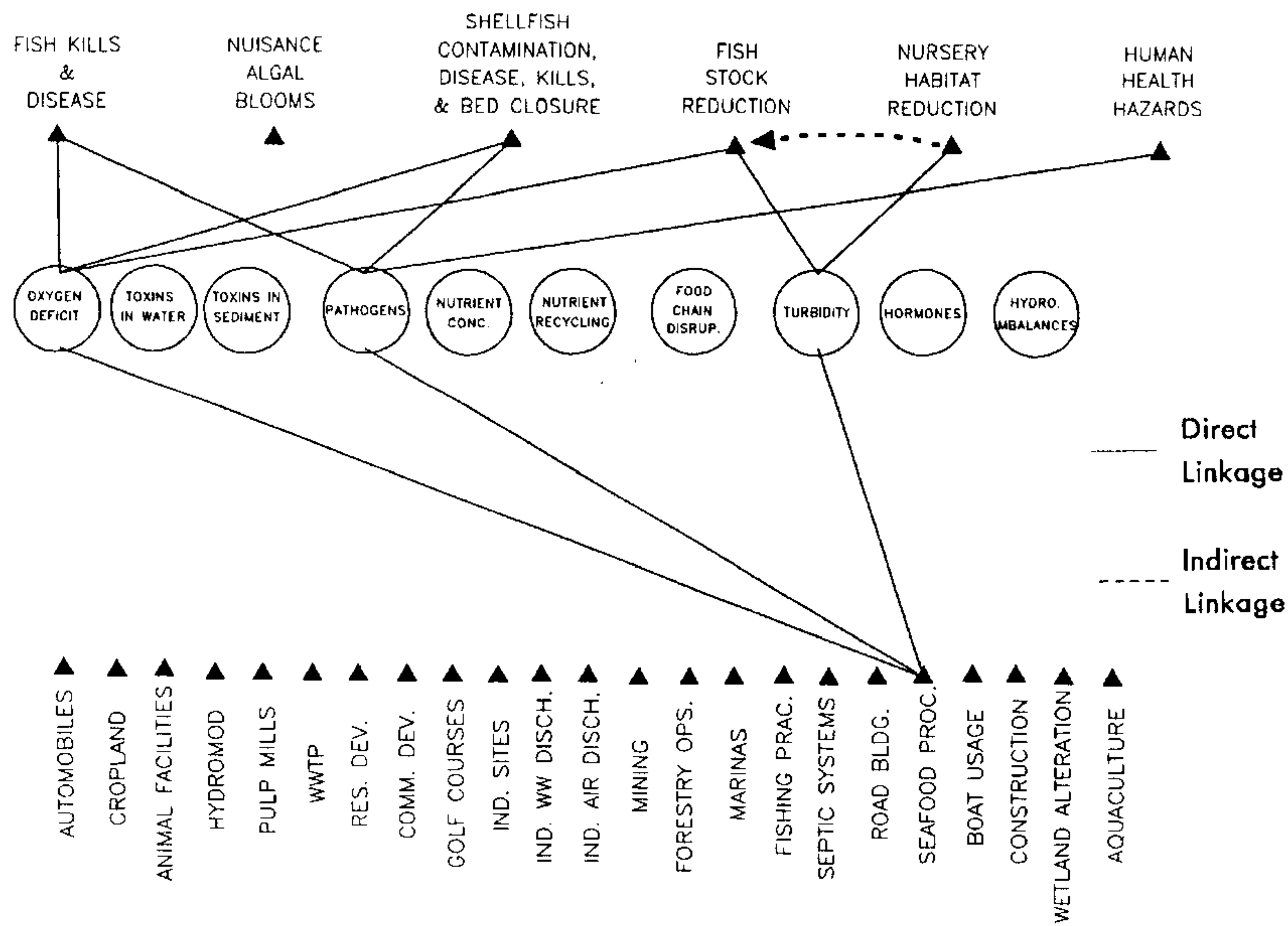

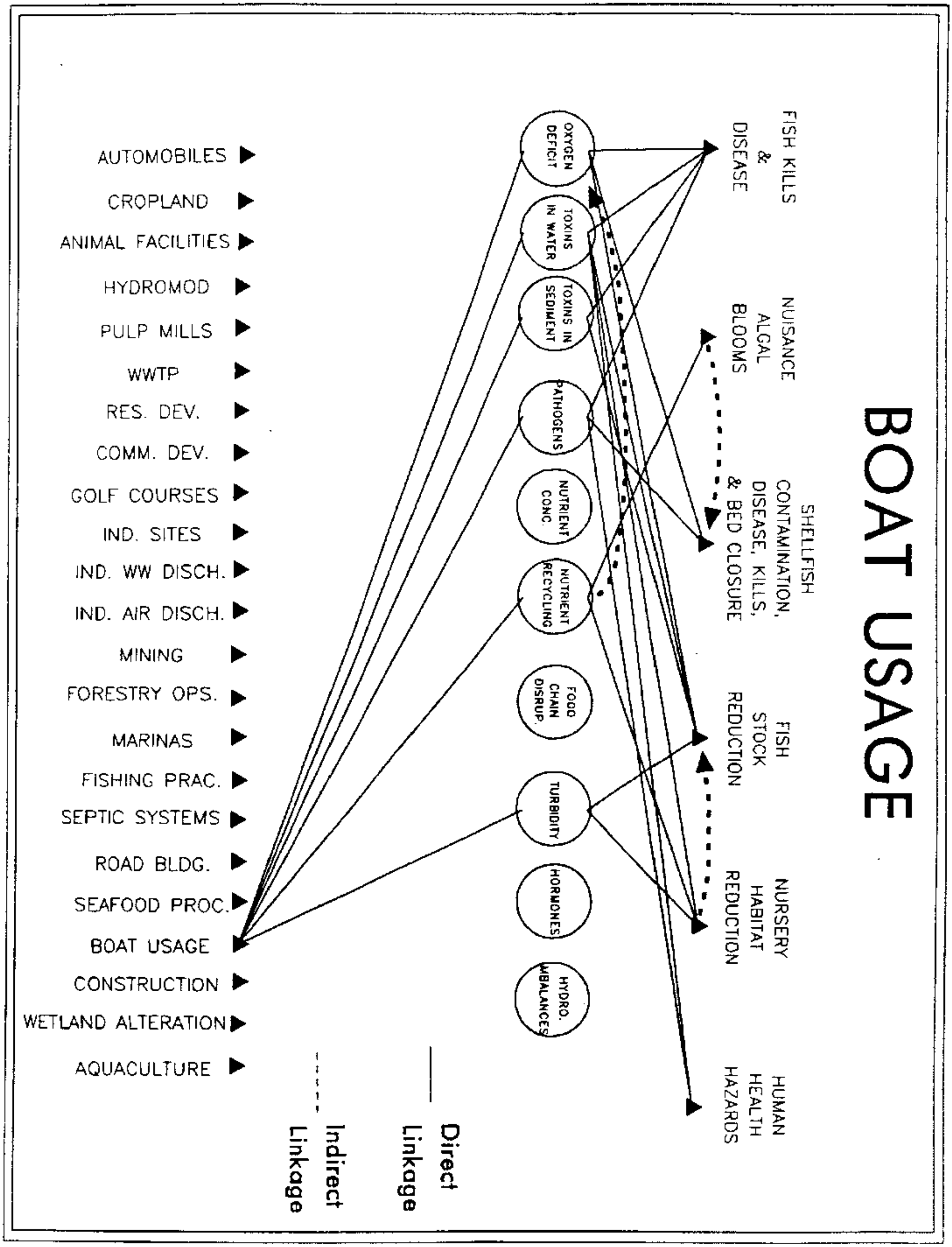
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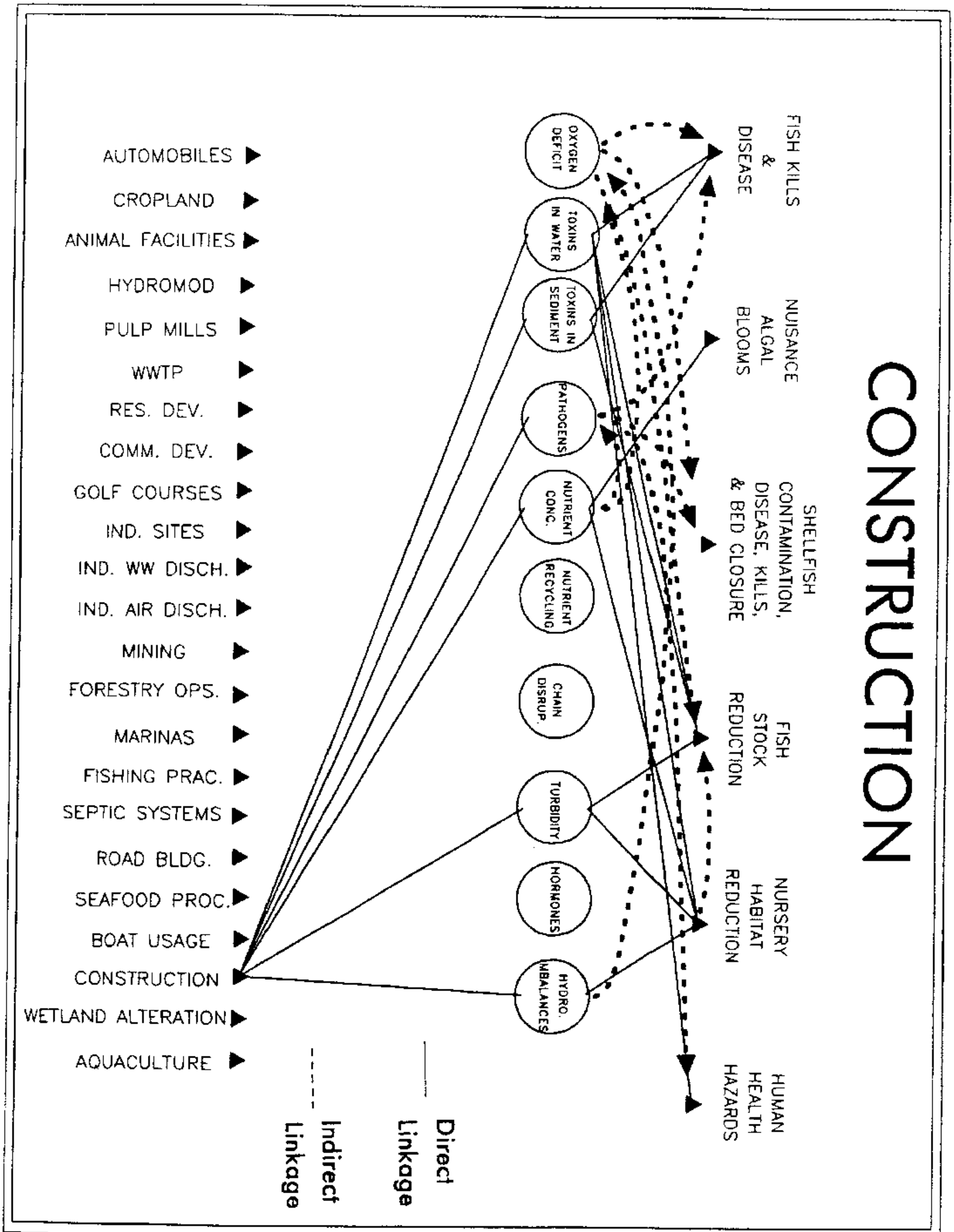
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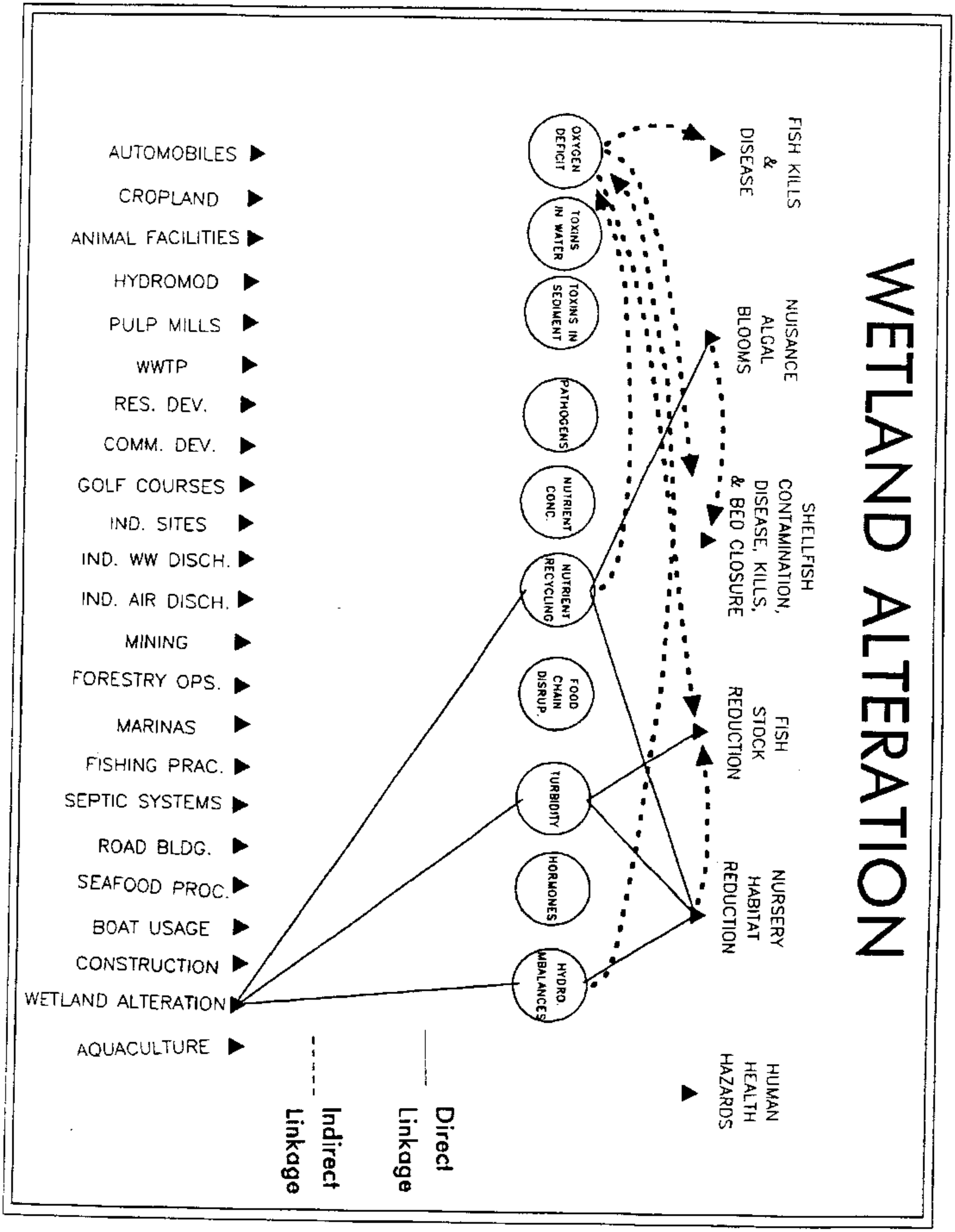

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