Lake and wetland impacts, West Coast Regional Water Supply Authority jurisdictional area

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The Southwest Florida Water Management District (SWFWMD) identified impacts of large regional ground-water pumping in the northwest Hillsborough and south Pasco county region as early as 1985. These impacts include lowered water levels in the Upper Floridan and surficial aquifers, saltwater intrusion, and adverse impacts to lakes and wetlands. In 1986, SWFWMD began the North Tampa Bay Water Resource Assessment Project (WARP) to develop a scientifically based management plan for the region. The WARP study includes all of the Central-West Central Florida Ground-Water Basin (all of Pinellas, all of Pasco, northern Hillsborough, and southern Hernando counties). The regional ground-water withdrawals are principally from the Floridan aquifer. A clay semi-confining layer partially restricts flow between the overlying surficial aquifer system and the Floridan aquifer. This leaky semi-confining layer controls the area's hydrology and its relationship to the overlying surface-water features. Three major stresses affect the region: rainfall, drainage alterations, and ground-water pumping. A numerical model developed as part of the NTB WARP, shows the growth of the impacts to the surficial system. Based on the results of the WARP, the SWFWMD developed Environmental Protection Standards (EPS) for four well fields. Although Pinellas County, St. Petersburg, and the West Coast Regional Water Supply Authority have challenged the EPS, SWFWMD intends to develop and apply EPS to all impacted areas in the region.

The Restoration Plan for Lake Apopka

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The Lake Apopka Restoration Project began in 1985 and will be complete when the lake has recovered. Recommendations by the legislature and the Lake Apopka Restoration Council were the beginning of the process that lead to the current restoration program. The plan for the restoration develops and changes as our understanding of this ecosystem increases and this process will continue as restoration activities begin to alter the characteristics of the system. The restoration plan is based on an understanding of present conditions and restoration goals. Limnological research areas included seismic profiling, bathymetry, hydrodynamics, hydrology, external nutrient budgets, internal nutrient processes, phytoplankton nutrient interactions, and zooplankton and fishery analysis. Analyses of the limnology of other, cleaner lakes in Florida, modeling of water quality under various nutrient loadings, and an ongoing review of the work being done in the field of lake restoration ecology provides the broader scientific context for the

restoration. Initial restoration goals for the lake developed into scientifically rigorous goals for lake water quality. Results of diagnostic and feasibility research were used to define the restoration program to achieve those goals. Feasibility studies included the use of water hyacinths, microbes, fish, and alum to clean the lake water; lake drawdown, lake level fluctuation, dredging, fish harvesting, marsh filtration, littoral zone restoration. Other concepts considered less formally include technologies such as the Algal Turf Scrubber, the use of Lemna (duckweed) as a nutrient filter, the use of high speed mechanical filters, and application of other chemicals used in lake management. The lake restoration program now includes the reduction of external nutrient loads, filtration of lake water though a marsh, harvest of gizzard shad, and littoral zone replanting for habitat restoration. Those methods are now being implemented or field tested. However, we continue to re-evaluate this project in light of additional knowledge and new technology. Additional diagnosis of specific areas may be still be necessary as the lake changes during restoration. Limnological monitoring will provide empirical validation or rejection of the predictions in the plan.

Aquatic herbicide safety

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Abstract

Herbicides are frequently the most reliable and least expensive means of weed control in Florida waterways. Many people worry unnecessarily over their safety to humans, wildlife and the environment.

The Environmental Protection Agency (EPA) requires extensive data on safety before an herbicide can be marketed. Toxicology studies are conducted on animals to evaluate safety to humans. These are single dose studies on rats, mice, rabbits, and chickens and long term feeding studies on rodents and non-rodents. Environmental site data are required to determine degradation in water and soil, movement in soil, groundwater contamination, and accumulation in irrigated crops, fish and other aquatic organisms. Wildlife and aquatic organisms are tested to determine acute and long term effects. The nature and duration of residues in plants, livestock, potable water, fish, meat, milk, poultry and eggs must be determined. Waiting periods must be established following treatment for swimming, use of treated water for irrigation and for drinking. Spray drift data and effect on nontarget insects and plants are required.

Problems in any area of data submitted may result in preventing registration of a candidate herbicide. EPA is highly sensitive to problems with long residual, bioaccumulations, ground water contamination, reproduction, carcinogenicity, teratogenicity and mutagenicity. Prior to registration no effect levels for toxicology must be established. Maximum food residues are set at 100 to 1000 times less than the no effect level of the most sensitive test. The tolerance level for drinking water is set at 20% of that for food.

Labels on herbicide containers provide mixing and application instruction, describe environmental hazards, safety measures for the applicator, and instructions for container disposal. When used according to label instructions, aquatic herbicides are safe and effective.

Introduction

Florida is blessed with warm weather, abundant rainfall, and a large number of shallow lakes and rivers. The state also has a large number of tourists, seasonal residents, and increasing numbers of permanent residents. Unfortunately large numbers of people moving about virtually guarantees that non-native weed species will be regularly introduced into Florida waterways. Once introduced, warm shallow water usually high in nutrients makes for easy establishment. Typically, introduced plant species have few enemies in Florida and rapidly become pests resulting in interference with irrigation and boat traffic, changes in fish and wildlife populations, and crowding out of native plant species.

There are many examples of such introduced weed pests, some of which are, water hyacinth, water lettuce, alligator weed, hydrilla, and torpedograss. The most desirable means of control is biological. The University of Florida, United States Army Corps of Engineers, and the United States Department of Agriculture have active research programs in this area, and there are some successes. Alligator weed is effectively controlled in Florida by the Alligator weed flea beetle. Water hyacinth and water lettuce are partially controlled by insects and diseases. There is intense effort to find biological controls for hydrilla, some of which appear to have potential for success. Mechanical weed harvesting is successful in limited circumstances but is too expensive for general use. Also mechanical harvesters available today often cannot keep up with regrowth of weeds.

Control of aquatic weeds in many of the rivers and lakes in Florida is dependent on the use of herbicides. Although herbicides are frequently the most reliable and least expensive means of control, many people are unnecessarily worried about some aspect of herbicide safety. Currently fewer than a dozen compounds have cleared all the corporate and government hurdles for registration as aquatic herbicides. These compounds have been carefully selected for their ability to kill weeds at concentrations that have little or no effect on other aquatic organisms, the environment, and the water consuming public. Following is a brief account of the discovery/development process, safety testing, and application standards for aquatic herbicides. Understanding these issues should greatly increase your comfort factor for chemical weed control.

The Corporation: Where Herbicides are Born!

The market for aquatic herbicides is too small for a corporation to develop compounds for that use only. The research effort is geared toward developing compounds for large row crop markets or total vegetation control. Once a

compound has been cleared for a major use the label may be expanded to include aquatic use.

The search for organic chemicals with herbicidal activity began in earnest after World War II. Typically, corporations with a large inventory of chemicals in stock tested them, hired more chemists to synthesize more compounds and obtained chemicals from outside sources such as university chemistry departments. These companies were bulk chemical companies. All compounds available were tested at random, with no pretest selection process. Simple greenhouse tests were devised to determine herbicidal activity. Usually a grass species (crabgrass) and a broadleaf species (pigweed) were seeded in 2 to 3 inch pots. Each compound was sprayed on the soil surface before seed germination and on young plants after emergence to get pre- and post-emergence weed control. Only one very high rate of each compound was used (10 LB/acre or above) and treatments were not replicated. This is referred to a primary screen and has two objectives. One objective is to test a large number of compounds. It is not unusual for a company to run 20,000 compounds through the primary screen in a year. The second objective is to eliminate compounds that have no potential as herbicides. Approximately 90% are not herbicidal. The 10% that show herbicidal activity are further tested in the greenhouse on a wide variety of weeds and crop plants to determine what weeds are controlled and what crop plants are tolerant. This is known as secondary testing and only about 1 in 20 are good enough to warrant continued testing. After secondary testing, a patent search is initiated. Those compounds that infringe on another company's patent are dropped. The few compounds remaining of interest after secondary testing and patent search are intensely studied by organic chemists. They conduct what are known as structural activity studies in which modifications are made to the basic chemical structure in an effort to improve the desirable traits of the candidate herbicide. A large number of new compounds are usually made and each one is submitted for evaluation in the primary and secondary herbicide tests. Not all compounds theoretically possible are made because of expensive starting materials, difficult synthesis or time constraints. At some arbitrary point in time, the series is patented and the best one or two compounds are tested in the field. Structural activity tests are never totally complete. Work on a chemical series may be terminated only to be resurrected by a new synthesis technique which provides the ability to produce additional compounds.

Testing compounds at random for herbicidal activity is still done. Now, however most companies have combined random testing with other methods designed to improve the probability of finding activity. The earliest method for improving the probability of finding activity was to review competitor patents and make additional compounds in the series just outside the patent protection. This has been highly successful as witnessed by the number companies marketing triazine herbicides and organic phosphate insecticides. Another approach is to computerize structures of known herbicides. The chemist manipulates chemical structures on the computer until it predicts desirable traits. The chemist then makes the compounds and biologists run them through the testing process. Recently companies have devised testing procedures for inhibition of some of the essential plant enzymes.

These tests can be conducted easily and rapidly which permits testing hundreds of thousands of compounds in very small quantities each year. This in turn improves the chance of positive results when tested on live plants. Compounds may be selected at random for enzyme screens or they may be designed by the chemist to react on various parts of the enzyme molecule. Generally, the various methods for selecting compounds to be tested improve the chances of obtaining a successful herbicide, but the random testing of all compounds available improves the chances of stumbling onto entirely new herbicidal chemistry.

Even after discovery of herbicidally active chemistry, the development and marketing of herbicides is a complex, expensive process carrying a high risk of failure. It takes about ten years and 50 million dollars to nurse a compound from initial discovery to label registration. During the development period, failure to pass any one of a host of safety tests will blow it out of the process, regardless of how promising weed control efficacy might be. Chemical companies test thousands of compounds each year for weed killing activity. Although hundreds of these kill weeds, less than one tenth of one percent successfully cross the mine fields of corporate profit requirements and government safety requirements to reach the market. The few that are sold must bear the cost of research on compounds that fail. Obviously, the longer a candidate herbicide is in the research process the more expensive it becomes. To save money, companies "weed out" compounds that lack potential for success as early as possible in the developmental process. Some of the reasons for early failure are: not active enough against a broad spectrum of weeds, rates required are too great, high acute toxicity to non-target organisms, starting materials are too expensive, manufacturing is too difficult, the chemistry is not patentable, the market potential is limited, or the compound is too volatile, corrosive, or explosive.

Unavoidably, some compounds are eliminated late in development, after expenditure of several million dollars. For example, cancer detected in test animals toward the end of chronic toxicology studies can cause compound failure late in development. Chronic toxicology studies cannot begin until information is available from acute and subacute toxicology tests, usually in the third or fourth year of development. Then the chronic studies themselves take three to four years to plan, conduct, and evaluate. Thus it is possible for a compound to have everything going for it until the eighth year of development before being eliminated. Some of the other reasons for late failure are long term persistence in the environment, bioaccumulation, toxic breakdown products, too much movement from the application site, resistance buildup in target pests, and large scale use resulting in problems from increased populations of non-target pests. In order to stay in business a manufacturer must have enough successful compounds to pay for several very expensive failures.

Pesticides (including herbicides) are produced by a few large corporations that depend on user confidence to sell their products. Although none would risk putting an unsafe product on the market, their principal objective is economic gain, not safety. Government mandated safety requirements assure that each product must comply with the same high standards thus reducing the temptation to cut safety

corners for profit. Companies must generate and provide safety data to the Environmental Protection Agency.

Government Data Requirements

The Environmental Protection Agency (EPA) is the federal agency charged with responsibility for licensing and monitoring use of all pesticides in the United States. Before an aquatic herbicide can be approved for sale, EPA requires submission of a large amount of data characterizing the compound, describing its use, and providing safety information. Following are categories of data requested along with a brief description of the major requirements.

Product Chemistry: Data submitted under this heading provides information on the basic nature of the herbicide. Included are physical and chemical characteristics such as melting point, boiling point, solubility, density, vapor pressure, corrosiveness, and stability. Also submitted are the structural formula of the active ingredient, starting materials, description of the manufacturing process, identification of impurities, and analytical methods for determining ingredients. Often companies change starting materials or procedures for manufacturing a herbicide either during the development process or after registration. Before changes can be adopted, information on product chemistry must be updated and resubmitted to EPA.

Residue: When a company determines how a product is to be used, directions must be submitted to EPA. Accompanying these directions, data must be presented showing how much residue there is in plants, water, irrigated food crops, fish and livestock, and how long the residue persists. Additionally, the nature of the residue must be determined, that is, whether it is the original material, breakdown products, or combinations of both. If a breakdown product accumulates over time, all safety evaluations must be determined for the breakdown product as well as the original chemical. The company must develop analytical methods for residue determination, and submit proposed residue tolerances to EPA.

Environmental Fate: Initiation of most studies in this section are dependent on information from residue tests, such as analytical techniques, projected use rates, type and persistence of residue, and proposed tolerances. First, studies are conducted in the laboratory to determine hydrolysis, photodegradation, volatility from treated areas, movement in the soil, and metabolism in aerobic and anaerobic soils. The laboratory studies are used to determine rates of application and sampling intervals for field studies. Field studies are conducted to determine dissipation in soil and water sediment and to determine bioaccumulation in irrigated crops, fish, and other aquatic non-target organisms.

Toxicology: Sometimes referred to as animal toxicology, this section is designed to evaluate the safety of herbicides and other pesticides to the general public. More space will be devoted to discussing toxicology because results of these studies relate most to human safety and results are most frequently quoted when referring to the dangers of pesticides. Scientifically, humans would serve as the most

accurate subjects for measuring pesticide toxicity, however, ethical considerations prevent this and animals are the best available substitute.

Test animals most frequently used are mice and rats. There are several reasons for this selection. They have a long history of laboratory use so there are many genetically pure lines available with well documented characteristics. They are small, adapt well to laboratory conditions, reproduce readily, and can be tested in sufficient numbers to be statistically evaluated without undue expense. They have a relatively short life span of two years which allows for lifetime and multigeneration studies. Finally, like humans, they are mammals. Other rodents are used for special tests such as rabbits for eye and dermal irritation tests and guinea pigs for skin sensitization tests. Dogs are generally used along with either rats or mice in subchronic and chronic feeding studies to provide information on another mammal. Monkeys are used occasionally if there is an indication that a compound might have characteristics uniquely toxic to primates. Toxicology tests are conducted in three stages; acute, subchronic, and chronic.

Acute studies are done early in the development of a compound. Test animals are subjected to single doses of the material over a wide range of concentrations. Three methods of application are required; oral, usually administered by syringe through the mouth directly to the stomach; dermal, in a paste to shaved portions of the skin; and inhalation, aspirated into an enclosed area with the test animals. Data are recorded on the number of animals killed and the clinical symptoms of survivors. Numbers usually presented in reports seen by the public are the dosages that were lethal to 50% of the test animals. These appear as oral, dermal, and inhalation LD_{50} values and are usually expressed as milligrams of compound per kilogram of body weight. The higher the number, the safer the compound. Acute toxicology tests serve two purposes. One is to establish rates of exposure for the subchronic tests. The other is to cease development of compounds that exhibit unacceptable toxicity. Another short term test usually conducted at this time is the Ames test. In this test, bacteria are exposed to the compound and observed for chromosomal abnormalities. Although not completely accurate, it serves as a predicator of genetic problems in higher organisms. Because of the potential for inaccuracy, development of a very promising compound will usually not be stopped because of a bad Ames test. Extensive feeding studies on animals will be relied upon for more accurate evaluation. However, the Ames test may tip the balance for or against a compound with some questionable attributes.

Subchronic tests are usually 90 days in duration and may consist of feeding, dermal, and inhalation tests. All aquatic herbicide candidates will be subjected to 90 day feeding studies and dermal exposure of at least 21 days and possibly 90 days. Feeding studies are done with a rodent species, usually, rats or mice, and a non-rodent species, usually dogs. All food provided the test animals for 90 days contains the test compound. Rates must cover a range sufficient for at least one rate to cause no measurable effect and one to cause a measurable effect. The effect can be anything that is measurable from reduced weight gain to formation of tumors. The rate range for chronic feeding studies must bracket the highest no effect level and the lowest effect level in 90 day feeding studies. Application methods for subchronic

dermal and inhalation studies are similar to those described for acute studies. These latter two studies are not continued into the chronic phase. However, if there is significant dermal exposure to the compound (as would occur for swimmers following application of an aquatic herbicide) additional studies may be required to determine the extent of dermal absorption and translocation in test animals.

Chronic feeding studies are done on a rodent and a non-rodent species. They are initiated shortly after birth of the animals and the compound is included in all feed for a 2 year period. All toxicological effects must be recorded with special emphasis for general metabolism, carcinogenicity, birth defects, reproductive effects, mutagenicity, and structural chromosome abnormalities. Offspring of treated animals are carried for two to three generations to observe any inheritable effects.

All animals that die during subchronic and chronic studies are autopsied to determine cause of death and to look for any non-lethal toxicological effects. At the end of the studies all living animals are sacrificed, representative microscope slides made from all tissue and the slide preparations observed by pathologists to determine any adverse effect of treatments not visible macroscopically. These slides must be catalogued and stored by the manufacturer for as long as the product is sold.

Wildlife and Aquatic Organisms: Candidate aquatic herbicides will have to undergo acute testing with several organisms. LD_{50} values must be determined for birds, usually mallard ducks and bobwhite quail. LD_{50} values are single doses that kill 50% of the test birds when applied orally by syringe. LC_{50} values will be required for fish (rainbow trout and bluegill) and aquatic invertebrates (mussels and crayfish). LC_{50} values are the concentration in water that kills 50% of the test organisms during an exposure period of 48 to 96 hours. Time of exposure and rate are reported when these values are used. Subchronic studies may also be requested including bird feeding and reproductive studies and fish life cycle studies. Bioaccumulation studies for aquatic organisms are required for most aquatic herbicides.

Applicator Hazard, Spray Drift, and Water Reentry: Response to EPA requirements in these areas can usually be satisfied by calculations based on publication and data collected for other compounds. For example, there is reliable research documenting exposure of a person to pesticides while loading a spray tank and spraying for a full work day. The data is available for several pesticide formulations, over a range of application volumes, and with a wide variety of equipment operated at several pressures. Equivalent information is available for dry application of granules and pellets. Application hazard for each type of application can be calculated based on the exposure data, frequency of exposure and mammalian toxicity of the compound. These calculations usually satisfy EPA requirements without having to run applicator hazard studies on each new compound. Considerable published data also exist on spray drift. EPA probably would not request additional data if the candidate herbicide is to be applied by conventional methods and has no physical or chemical properties that would increase drift problems. Water reentry restrictions following aquatic herbicide application are also determined by application rate, rapidity of breakdown, and toxicology of the compound.

Product Performance: Although EPA has the authority to request data on performance it is not presently doing so for aquatic herbicides. The logic being that the market place can adequately evaluate performance and that the agency should devote its full time to protecting the safety of the public and the environment.

Field testing: Even though EPA does not request performance data they do mandate guidelines and monitor field testing. Ordinarily, companies conduct the first field tests on their own property in self contained ponds or above ground pools. These are infested with the weed species they hope to control and desirable plant species they hope will survive. If efficacy results are promising and early data on toxicology, residues, and safety to wildlife and the environment are acceptable, off company research is initiated. These first tests off company property are limited by EPA to a total of 10 acres per year within the United States. In the case of aquatic herbicides, they will typically be in small ponds without an outlet. If the compound is already registered for another use, for example as a paddy rice herbicide, much more will be known about its safety, and EPA may permit the 10 acres to be in one or two experiments in larger bodies of water.

Upon completion of the small scale testing, and when enough safety data are available to be reasonably certain the compound has no characteristics blocking registration, EPA is petitioned for an experimental permit.

An experimental permit allows large scale testing using commercial methods and equipment, however EPA maintains tight control over the entire process. All safety data available will be submitted by the manufacturer to EPA along with an experimental label and amount of compound requested. The label will provide information normally present for a fully registered compound. In addition it will state the rate range to be evaluated and company representatives responsible for managing the permit. The petition must request a specific quantity of compound, by formulation, for each state in which testing is anticipated, the number of acres to which it will be applied in each state, and length of time requested. EPA may ask for more information, accept, or reject a petition. They may also accept it for fewer acres, less time, or less quantity than requested. After approval, the company must provide quarterly reports to EPA detailing quantity, date, formulation, and destination of all compound shipments. After applications begin, the location, quantity of compound used, and area treated must be reported. At termination of the experimental permit, accounting for all compound must be made to EPA, and all not used must be shipped back to the point of origin. Before application, state regulatory agencies must be informed of the anticipated experimental permit in their state. Even though approval is granted by EPA, individual states may block the use in their state. State and federal regulatory representatives have the right to be present when applications are made and to visit the site after application.

EPA Standards for Safety

EPA has a staff of qualified biologists, chemists, and toxicologists that propose safety standards. Proposed standards are opened to public comment before being initiated. Additionally, from time to time task forces of outside scientists review and

suggest changes in safety standards. These standards are used to determine safety of a candidate herbicide to the environment, non-target organism and humans. EPA will usually not approve a compound that is highly persistent or bioaccumulates in the environment. Many environmental judgments are based on the characteristics of the compound, application site, and nature of the residue. For example, an aquatic herbicide might be acceptable if there is still a 5 % residue that is tied up in the hydrosoil for one year after application, and is being slowly released into the water column. Whereas, a herbicide residue of 1% in the water column one month after application might not be acceptable. A terrestrial herbicide applied to soybeans that leaches into the water table, even in barely detectable amounts, might not be acceptable, whereas an aquatic herbicide, with greater safety, could have an acceptable tolerance in drinking water. Safe residues for non-target organisms must be less than that producing an effect level in toxicology tests. However, unacceptable residues may be made acceptable with label restrictions. For example, imposing a waiting period to allow breakdown of the herbicide to a level safe for watering livestock, swimming, or irrigating crops, or allowing treatment of only a portion of a body of water at one time to prevent fish kill.

The most restrictive safety standards are for residues in human food and drinking water. Maximum food residues are set at 100 to 1,000 times less than the no effect level observed in the most sensitive toxicology tests, usually the chronic feeding studies. The level of safety required depends on the type of effect the compound has on test animals and how many food sources have residues. If use of a compound will result in residue on only one food source the safety factor can be lower than if it results in residues on two or more food sources. The safety level arrived at assumes an individual can consume the maximum allowable residue from all sources every day of their life without practical risk. The residue level arrived at by this method is called the Acceptable Daily Intake (ADI). The acceptable Daily Intake for drinking water assumes an individual will consume two liters (approximately two quarts) of water every day of their life and is set at 20% of the concentration of the ADI for food. Of course, as a practical matter, no one will ever be exposed to the maximum allowable residue of any pesticide every day of their life, so actual safety margins are much greater than the calculated ones.

Monitoring Safety Data

Delegating responsibility for generating safety data for candidate pesticides, to the manufacturer makes sense economically but may seem a little like asking the fox to guard the hen house. However, EPA has a monitoring system in place which effectively keeps the fox away, and the data collectors honest. Federal law requires companies to hire quality control people, who are not involved in conducting experiments, to monitor compliance with good laboratory practices and take personal responsibility for accuracy of data presented to EPA. Requirements for compliance with good laboratory practices are issued by EPA. They also set qualifications for persons involved in the testing. Companies must maintain protocols for all tests, with any changes occurring during their conduct explained, and initialed

by persons involved. All raw data must be signed by the investigator and a witness, and be kept on file as long as the product remains on the market. EPA representatives make periodic spot checks on corporate laboratories. During these checks they have authority to interview all company employees and review all raw data.

Enforcement of Safe Applications

After a company has collected all the data required by EPA, and satisfied its own requirements for marketing, a petition for full registration is submitted to EPA. The petition will be accompanied by data, a statement of justification for registration, and a proposed label. EPA representatives carefully review the package and may confer with outside experts, a process usually taking twelve to eighteen months. Upon approval the label becomes a legal document for safe application (it is illegal to use a product inconsistent with the label). Any label change must be approved by EPA and if any adverse effect of a compound is discovered after registration EPA may take it off the market.

Most commercial applicators of aquatic herbicides in Florida are licensed by the state. To be licensed applicators must pass tests for safe use of pesticides in general, and specifically for aquatic herbicides. The state provides opportunities for training and administers the tests. Once licensed, the applicator must participate in continuing education to maintain the license. Additionally, all herbicide applications to public waterways must be described in writing, and submitted for approval to the Florida Department of Natural Resources.

The pesticide industry is one of the most regulated industries in the United States, and aquatic herbicide use is the most regulated portion of the industry. No human endeavor is perfect, but there is very little likelihood of mistakes occurring with aquatic herbicides that would endanger the environment or the public.

Structure and dynamics of sublittoral zone benthic invertebrate communities as indicators of lake Okeechobee trophic status

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Benthic invertebrate communities of the Lake Okeechobee sublittoral zone were sampled to ascertain the influence of advancing eutrophication upon biotic components of an ecosystem unique to North America. Overall, the benthic fauna was found to be dominated by segmented worm and immature insect species noted for tolerance of low dissolved oxygen and redox conditions characteristic of habitats impacted by organic pollution. Of the 97 invertebrate taxa collected, only five occurred in numbers large enough to account for more than five percent of the total organisms. Cluster analysis of the dominant species data matrix revealed the existence of three major species assemblages. Each assemblage was associated with a specific habitat zone. Ordination of the symmetrical matrix derived from similarity

index comparison of each two station combination indicated the tolerant species assemblage associated with the mud ecological zone also inhabited sand substrates near inflows draining the northern Lake Okeechobee watershed. Comparisons with benthic communities of other Florida lakes showed that Lake Okeechobee ranked among lakes considered hypereutrophic. Duplicate method comparisons with 1969-70 Lake Okeechobee data indicated species composition and species richness have remained unchanged, but community diversity and evenness of distribution have declined significantly. During the 20 year period, relative abundance of segmented worms increased by 50 percent, while relative abundance of taxa exclusive of segmented worms and midges declined a corresponding 50 percent. Community structure shift comparisons indicated Lake Okeechobee has exhibited eutrophication response patterns similar to those of temperate lakes which ultimately became dominated by undesirable invertebrate and fish communities.