Aquatic Weeds And Man's Well-Being

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INTRODUCTION

What is the value of thinking about the relation of waterweeds and the physical and mental state of man? The subject forms no composite whole and will never be one. Yet the ancient problem can be viewed from normally unused angles. With current public acceptance of some unpleasant facts in the fields of human population increase, food and water supply, and air and water pollution, there is a growing reverence for conservation of natural resources whether it be expressed as a birth control pill, development of fungus resistant wheat, conversion of salt to fresh water, regulated usage of exhaust reducers in vehicles, or the simple contemplation of the present condition of the stream in which one swam as a child. Within this melancholy framework there is space for outlining some of the ways in which natural plants which live in or near waterbodies affect the health and equanimity of man. Such a resume cuts across several disciplines of natural history, and the supporting data are hidden in many bibliographic niches and in the memory of biologists (22).

Water then is our basic interest and weeds—defined as a plant in the wrong place, wrong population density, and serving wrongly—are defined as pollutants, *sensu strictu.* To the farmer whose pond use has been destroyed by an almost impenetrable cover of water lettuce, each plant of the *Pistia* is a particulate pollutant. In the lay concept water pollution means sewage contamination firstly, and industrial wastes secondly. In the technical concept the most important vital component of the debased aquatic ecosystem is the bacterial-mycotic complex (27, 32). Here we think of bacteria as aquatic plant life in the polluted maze.

SPECIFIC PROBLEMS

Water Supply and Pollution

Since by the year 2000 we shall need 35 percent more unpolluted water than will be available, the present supply must be kept usable and used and re-used. The aquatic budget is limited, finite. All we can do is locate water, decontaminate it, transport it, and be prepared to exert eternal vigilance in its proper maintenance (2). In the United States of the total annual precipitation in 1966, only 8 percent was used by man; 71 percent evaporated; and 21 percent was returned to the ocean (32).

Although the term "bacterial flora" is glibly used with reference to microbiotic residents of the human gut, the public does not connote these key organisms as the plant life they are. The current pollution problem in American waterbodies is an appalling example of the significance of bacteria whether they are pathogenic or not. The natural biological cycle in aquatic environments is still a fact, and what a fact! The key element in the normal cycle is oxygen and the key aquatic plant is the bacterium which converts soluble organic matter into other bacterial cells and into inorganic elements. The inorganics are absorbed by algae and metabolized into other algal cells. Both cell types become food for protozoans, rotifers, and crustaceans. Some of the bacteria, algae, and animal life serve as basic food for minnows and young fish; small fish are devoured by large fish. Man "gets into the act" by discharging his wastes into the waterbody where the bacteria metabolize the organics; the cycle is then completed (2, 4, 15, 27, 32). Thus, a certain amount of waste discharge into streams, etc. is normal and biologically required.

However, if organic waste concentrations increase over normal, bacterial populations explode with an increasing demand for oxygen (BOD) and as this life-giving element decreases, the higher animal forms perish: game fish first, followed by crustaceans, rotifers, and the higher protozoa (32). Bacteria remain dominant and in the absence of dissolved oxygen (DO), undergo anaerobic metabolism producing vile odors and black water. Man thus fouls his aquatic ecosystem. The publicized statement that it required 100 years of varied pollution to bring Lake Erie to the current status of a massive cesspool is a monument to the strength of that elemental aquatic plant, the water-fouling bacterium (12). In contrast, management of fishing ponds and lakes is now an advanced art providing both beauty and recreation (25).

Taste-Odor Problem in Water Supply

Public acceptance of drinking water supplies, whether purified or not, hinges to a great degree on the absence of detrimental tastes and odors. If the poor taste and odor are of chemical origin, saline or sulphurous, the public is resigned to its fate; but if of microbiotic origin, great clamor is raised and the sanitary engineer is expected to defy nature with all due haste and bring the supply back to the level to which the user has become accustomed (15). Remarkably enough, *Standard Methods,* the Bible of water supply engineers, has stimulated codification and description of the common odors that may emanate from the domestic tap (4). These are spicy, balsamic, geranium, nasturtium, sweetish, violet, chlorinous, hydrocarbon, medicinal, sulferetted, earthy, peaty, grassy, musty, moldy, vegetable, septic, fish, and pigpen! Abatement of taste-odors is not easy and at times impossible for a particular season.

There is much accumulated information on the kinds of algae implicated and recent studies show that the actinomycetes are potential troublemakers. Blooms of microorganisms die and release certain oils which cause the undesirable taste-odor problems. Good crops of algae and actinomycetes result in agricultural areas where run-off carries fertilizer residues into impoundments increasing the phosphorous content (7). In impoundments which receive treated or untreated sewage, the algal problems may well be increased by the use of polyphosphates in household detergents. At certain population levels algicides must be applied (5). The most common one is copper sulfate applied at 0.1-1.0 ppm in only the upper 10 feet of the reservoir (27). Since the algicide kills the protozoan predators of bacteria, there is a temporary surge of the latter organisms. In treatment plants activated carbon, chlorination, and aeration are the indicated treatments to alleviate the problem should reservoir source treatment not suffice (15).

Health-Related Arthropods

Malaria.—This significant disease is gradually being brought under control internationally (3). As indication of its recent seriousness, in 1957 of 36 great diseases, it ranked fourth in morbidity with 4,153,250 cases reported of a population of 1.25 billion, and third in mortality with 310,842 fatalities attributed to it (14).

Water plants are favorable to anopheline mosquito production. For example, in Puerto Rico, this includes coontail, fanwort, widgeon grass, waterweed, pondweed, stonewort, bladderwort, and filamentous green algae, especially *Spirogyra*. Also, the most important of the wetland or semiaquatic plants are Para grass, Carib grass, tropical carpet grass, sour paspalum, and small trumpet grass. Malaria mosquito larvae are inhibited by the duckweeds, waterfern, water hyacinth, water lettuce, pond lilies, and water snowflake, certainly by total cover and probably also by associated water quality changes (30, 31). Iron bacteria, productive of rust-colored flocculent masses and an oily surface in stagnant water, almost totally repels anophelines. Research by Tennessee Valley Authority provided leads on the beneficial reduction of anopheline-supporting vegetation by seasonal manipulation of reservoir water levels (1, 22).

Great advances have been made in recent decades in development of pest mosquito control districts which are designed to improve public health. Control efforts are directed at abatement of these pests in urban areas although Culicoides, or "no-see-ums", is also an object of attack in places. As an important part of these local tax-supported programs, much is done in the off-season to remove ditch bank vegetation by herbicides and cutting equipment.

Recreation facilities imply healthful recreation. In the United States 41 percent of the population prefers water-based activities to any other. This is shown clearly in the booming development of family-type recreational facilities at large public hydroelectric reservoirs. Here it is mandatory that aquatic weeds should not become detrimental to fishing, swimming, boating, or esthetic interests, and as such are a key facet in the mosaic of a specialized healthy environment much in demand.

Arboviruses

Sleeping sickness or virus encephalitis has been a problem in parts of Latin America and the United States for decades. During 1926-1950, 27,749 human cases were reported for the states: the lowest number, 702 in 1932; the highest, 3,516 in 1941 (17). Only a few hundred cases have been reported annually during recent years. The decrease is most probably due to health education, better screening of houses, and promptness and efficiency of mosquito control incident to epidemics. Larvae of *Culex tarsalis,* the feared vector of St. Louis and Western encephalitis in midwestern and western United States, thrive in vegetation-clogged irrigation and drainage ditches, seeps and roadside impoundments (11, 21, 22). Two other species, *pipiens* and *quinquifasciatus,* are not vegetation associated, but prosper in domestic containers, catch basins, cesspools, and filthy ditches. All mosquito larvae except *Mansonia* must breathe at the water surface. *Mansonia,* host of Eastern encephalitis, is unique in that both larvae and pupae derive their oxygen by puncture from air trapped in hollow plant stems (21).

Dengue fever normally of low endemicity exhibits occasional outbreaks as in Panama in 1941, Yemen in 1954, and Puerto Rico in 1963 (24). In the 1963 Puerto Rican epidemic, infections reached 33,000 in a population of 2.5 million. In a carefully monitored urban population, the prevalence was 35 percent. Dengue does not kill, but the word "miserable" describes the illness adequately (19). Yellow fever fortunately remains at a low ebb in the Old World and has been reported in man but a few times in recent decades in the Americas (14). It remains endemic as a sylvan animal form in limited parts of Latin America (19). *Aedes aegypti,* vector of both dengue fever and yellow fever against which there is a Western Hemisphere eradication program, lives well with inside water plants but is otherwise confined to breeding in outside artificial containers (11).

Some fifty mosquitoes representing *Culex, Aedes, Mansoni,* and *Anopheles* are reported to be natural or artificial vectors of filariasis or elephantiasis in the tropics and subtropics. Other diseases borne by mosquitoes are tularemia (Swedish), fowl-pox, and Rift Valley Fever (16, 19).

Mosquito species are attracted to particular aquatic habitats for egg laying and development of the larval stages. In the water quality intergrades from well-balanced to oxygen-poor, all species fit in (11). As the quality of water changes so does the mosquito fauna capable of living in that ecosystem. Of possible interest here is the gradual dominance of culicines over anophelines as impounded or sluggishly flowing water becomes degraded by total plant coverings or by massive plant decomposition. Conceivably, this could provide a new habitat for important disease vectors of encephalitis instead of commonly resident pest mosquitoes.

Other arthropods of public health interest linked permanently with waterweeds include snipe flies, tabanids (horse flies, gadflies, deer flies, and greenheads) Clear Lake gnats, May flies, sewage flies, black flies, sand flies, and tsetse flies (21, 22).

The tabanids and sandflies or "no-see-ums" are fierce biting pests which seriously affect use of tourist and recreation areas (22). Larval development takes place in weedy roadside pools and rice paddies. However, semiaquatic habitats are utilized by some species seasonally. In the southern United States cattle may suffer greatly from bites and this must affect meat and milk production adversely. In the United States tabanid species carry tularemia, and in African countries *Chrysops* transfers the eye worm, *Loa loa* (28). The New England black fly pest problem is well known to the tourist industry. Control of stream-side vegetation has become an effective means of reducing tsetse fly vectors of African sleeping sickness, or trypanosomiasis, near endemic villages (21).

Breeding in vegetated margins of both fresh water and brackish water swamps, the "no-see-ums" occupy extensive environments on the Atlantic and Gulf Coasts and in the Caribbean (24). The principal offender, *Culicoides furens,* is well named. Its bite can immobilize highly reactionary victims, and it has been incriminated as the vector of one of the minor filarial worms, *Mansonella*, in the Caribbean.

In the Great Lakes area asthmatic attacks occur in recreation groups due to contact with wing dust from massive shoreline production of May flies (21). The non-biting Clear Lake gnat of the Northwest United States poses significant nuisance problems in the summer simply by density of adult insect populations.

Another most undesirable urban pest is the Psychodid sewage fly borne massively at times in sewage treatment facilities and in oxygenation ponds (15, 24). Its potential for mechanically carrying pathogens to contacted persons would seem to be unlimited.

Worm Diseases

Aquatic plants are definitely associated with the world of worms affecting man. The key point is that the snail vectors and the larval stages of the parasitic life cycles are held in abatement naturally by animal predators: (1) by duck, turtle, and fish consumption of snails; (2) by fish ingestion of crustaceans (crayfish, crabs, copepods); and (3) by fish predation of both miracidial larvae infective for snail intermediate host and cercarial larvae infective for the final host, man. Numerous flukes of fish, amphibians, reptiles, and other insectivorous animals use aquatic arthropods as hosts such as dragonflies, caseworms, May flies, and stone flies (16, 24, 28). Considerable research data are available on the ability of guppies to control the cercaria of the human blood fluke life cycle (29), which involves some 200 millions of cases internationally. Significantly, in order for predators to operate efficiently they must not be impeded by masses of aquatic vegetation and in this sense, a waterbody relatively clean of waterweeds is judged to be a safer place than a vegetation-clogged one located in endemic foci of certain helminthic diseases (18, 22).

Correlations between the presence of snail hosts of the various trematodiases, especially the schistosomes, and aquatic plant preferences have been worked out in ecological surveys fundamental to control planning in many countries. In Puerto Rico, for example, of the 38 aquatic plants (30), the *Biomphalaria glabrata* association is good in 14 instances and of these, it is generally consistent in arrowhead, elephant's ear, stonewort, and water hyacinth; it is fair in 9 instances, and poor in 14 instances (18). *Caladium*, or elephant's ear, which grows in and marginally to small sluggish streams, is the best snail indicator plant. It provides shelter, semishade, and a rich source of snail food in disintegrating leaves, stems, and roots. In fact the roots are sliced, dried, and ground to become an important ingredient in a special diet for mass production of all laboratory snails.

Some parasitoses representing flukes, tapeworms, and roundworms (16, 24, 28), which have stages vulnerable to predation, may be listed along with respective host and the larval stages, shown parenthetically: filariasis which attacks some 250 millions of persons (Mosquito larvae); Chinese liver fluke, *Clonorchis* (Buliminid snails, miracidia, and cercaria); cattle and sheep liver flukes, *Fasciola hepatica* and *F. gigantica* (Lymnaeid snails, miracidia, and floating cercaria); broad tapeworm *Diphyllobothrium* (crustacea); guinea worm, *Dracunculus* (copepods); giant intestinal fluke, *Fasciolopsis* (Planorbid snails, miracidia, and cercaria); Asiatic lung fluke, *Paragonimus* (Thiarid snails, crabs, crayfish, miracidia, and cercaria); blood flukes, *Schistosoma* (Planorbid snails, miracidia, and cercaria); and avian schistosomes responsible for swimmer's itch (several snail genera, miracidia, and cercaria).

Although the larvae of the blackfly *Simulium*, vector of onchocercosis, are aquatic, these insects are not always plant associated, the larvae cases being attached to rocks in clean rapidly flowing streams in the mountains. They breed also in low velocity drains. Other kinds of these water-based flies affect the health of economic animals as vectors of poultry disease or, as noted, as important blood-sucking pests of domestic cattle, for example, the Southern Buffalo Gnat (21).

Significantly, the giant intestinal fluke infection is obtained through the Asian custom of eating raw aquatic plants—water chestnuts, lotus parts, water bamboo, and water caltrop—on which cercariae are encysted (19). Normally, liver fluke infection occurs when encysted cercariae are ingested with grass, etc. Thus, herbicide application might provide some control but would not affect floating encysted cercariae normally drunk by cattle. *Fasciola* can be a human health problem, as for example, in Arequipa, Peru, where cercariae encysted on watercress are ingested in salads.[1]

Keeping waterbodies comparatively free of weeds near human habitation in areas endemic for the diseases noted above could become a reality with greater frequency because of the availability of efficient chemical herbicides (1, 2, 5, 7, 20, 23, 26, 31) and biological control techniques (1, 8, 9, 10, 13, 17, 18, 26, 34, 35, 36). The combination of chemical herbiciding and biocontrol of water plant pests has been strikingly illustrated in a film recently produced by the Central and Southern Flood Control District, Florida, entitled: *Marisa* and the Mermaid. As shown, chemicals designed for specific control of surface matting water hyacinth, etc. are applied along with the use of the manatee and the large snail, *Marisa cornuarietis*, for control of rooted submersed plants such as *Elodea*. *Marisa* has a two-pronged attack since in addition to reducing the aquatic weed problem, it is an efficient predator of the snail intermediate hosts of *Schistosoma mansoni* and *S. haematobium*, schistosomes common to Africa, the Mediterranean, and parts of the New World. In addition, it can destroy the Lymnaeid vectors of cattle liver fluke, but since these snails are amphibious, herbicidal removal of vegetation is probably of no import.[2] The idea is that although liver fluke infestation in a particular pond or stream may possibly be eradicated by fish predation of floating cercariae and by *Marisa* eradication of the vector snails within the waterbody and at the margins, the snail continues to thrive in the adjacent humid soil-plant complex. Regional usage of the technique instead of focal application is the indication. In this connection, in laboratory observations another fairly large water snail, *Pomacea australis*, discovered in Belo Horizonte, Brazil, to be a predator of the Brazilian blood fluke snail, *Biomphalaria*, has been found to be an avid eater of certain kinds of waterweeds (6).

The current list of known animals which are useful biocontrol agents of aquatic weeds (18) includes the snails, *Marisa* and two *Pomacea*; ducks—for example, black muscovies (5); several fishes (species of *Tilapia* and the Chinese grass carp, *Ctenopharyngodon idella*); the beetle, *Agasicles*, consumer of alligatorweed (36); the aquatic wingless grass-

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[1]Personal communication: Dr. Jorge Chiriboga, Asst. Director, Puerto Rico Nuclear Center, Rio Piedras, Puerto Rico.

[2]Author's observations, 1964-1968.

hopper, *Paulinia*, eater of waterfern (8); and the manatee which ingests both floating and rooted plants.

Toxic Shellfish and Fish

Another kind of weed, "seaweed," certain types of plankton termed Protista, are basic to a serious form of human intoxication—shellfish poisoning—and cause disasters in marine biology (33). The shellfish poison is one of the most lethal known; the minimal lethal oral dose for man is thought to be between 1-4 mg/kg of body weight. Clinical effects are not completely understood but the heart is definitely harmed. Death is usually attributed to respiratory paralysis. Protista are single-celled animal-plant organisms in that their energy is derived through photosynthesis and their motion through flagellation. Widely distributed in marine waters, they reach public attention as blooms of "red tide," "red water," etc. Massive fish destruction may accompany these blooms which are produced by a variety of environmental changes. The cause for mass mortality of marine life during and following the blooms is not clear, yet the best evidence points to physical rather than chemical factors.

Paralytic shellfish intoxication is caused by certain molluscs and a few echinoderms and arthropods which have eaten toxic Protista (dinoflagellates) and are then ingested by man (33). Some 21 dinoflagellates have been implicated the best known of which is *Gonyaulax catenella* of the Pacific coast of North America. How the poison accumulates in molluscs is unknown. At least 28 species are involved including commonly known forms—clams, mussels, oysters. Mostly the toxin is concentrated in the digestive glands of the mollusc. A non-paralytic form of poisoning may be contracted in Japan by ingestion of certain clams, oysters, and gastropods which consume toxic plankton.

Ichthyotoxism is a very complex subject (24, 33) viewed either scientifically or as a basis for folklore. At least 16 factors have been studied as the probable cause of concentration of very potent toxins in the tissues of various marine fishes. For a brief reference to the extensive subject the most important form of fish poisoning which implicates over 300 species is called ciguatera, and it seems certain that it is associated with the food-chain relationship of the fishes. Probably the toxin originates in a benthonic organism which is eaten by herbivorous fishes in turn to be consumed by carnivorous ones. The latter fishes accumulate poison without being harmed. Herbivores feed on toxic algae, fungi, or the Protista and the current evidence favors the blue-green algae as the most probable causative factor. Clinical symptoms resemble those of shellfish poisoning.

Beneficial Seaweeds

All aquatic weeds are not detrimental to man's welfare. Seaweeds have formed the basis for a useful maritime industry for many decades from which human and animal food, medicinals, mucilages, bacterial medias, fertilizers, and various inorganic and organic extractives are taken (33). Although the bulk of the industry, which is mostly confined to coastal reaches of the temperate zone, is concerned with extracting organic compounds, there is continuing research on seaweed utilization as animal food. Six species are currently eaten by cattle as fodder and various ground meals are used as dietary supplement. Meals which have a higher vitamin-mineral content than dried grasses are useful components of sheep food, but are objectionable in poultry food. Use as organic fertilizer is mostly limited to coastal area farming and is supplemental in nature. For man seaweeds have a relatively low protein and fat content. Although there is carbohydrate available the digestion of algal polysaccharides is poor. Efforts to make the polysaccharide acceptable by enzymic predigestion are under investigation.

Seaweed stands are harmed by both fungal and bacterial disease. Low sewage contamination favors growth; high concentration is destructive. Fuel oil contamination is decidedly harmful. Seaweeds absorb various types of contaminating radioactive materials. Interestingly, seaweed production is adversely affected by several browsing animals—limpets, barnacles, sea urchins, sea hares, and some kinds of fishes.

SUMMARY

Aquatic vegetation harms human health in several ways since water-related diseases are still part of our environment. Malaria has receded internationally due to chemotherapeutic-insecticidal programs, but recently has resisted both medicines and insecticides. Lately, active malaria cases in the United States were kept to fewer than a dozen annually; in 1967 the figure was about 700, almost all traceable to returning military personnel. Other diseases exist whose transmission is indirectly affected by aquatic weed conditions: filariasis, and various trematodiases especially the schistosomes, Chinese liver fluke, cattle liver fluke, Guinea worm, giant intestinal fluke, Asiatic lung fluke, and the broad tapeworm.

Waterweeds support other disease-pest arthropods: snipe flies, tabanids (horse, gad, deer, and greenheads), Clear Lake gnats, May flies, black flies, sandflies, and sewage flies.

Bacteria in the wrong place and in harmful population density degrade the health of urbanized man, and as water pollutants, require upgrading and maintenance of all waterbodies. *Lay understanding of conservation must include management of aquatic vegetation.* A pest plant should be removed mechanically, by chemical herbiciding, or by recently developed biocontrol techniques, which use several plant-eating snails, fishes, ducks, the manatee, and aquatic insects. Weed removal allows the natural or introduced predators of the larval stages of the fluke infections to operate without mechanical hindrance near habitations in endemic areas. Seaweeds must be protected from coastal pollution to insure the future of a growing industry giving human and animal food, medicinals, mucilages, bacterial media, fertilizers, and various organic compounds. Marine Protista serve to toxify edible shellfish and fish, and become a serious threat to consumers. "Red Tides" of the Protista somehow destroy fish and other marine life. Control of freshwater aquatic weeds strengthens the alliance between agriculture, navigation, and public health, and will serve man's survival in the 21st century.

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