UNITED STATES
DEPARTMENT OF THE INTERIOR
Julius A. Krug, Secretary

FISH AND WILDLIFE SERVICE
Albert M. Day, Director

Special Scientific Report No. 39

EFFECTS OF AQUATIC WEED INFESTATIONS ON THE FISH AND WILDLIFE OF THE GULF STATES

By

J. J. Lynch, J. E. King, T. K. Chamberlain
and Arthur L. Smith, Jr.

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Explanatory Note

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TABLE OF CONTENTS

INTRODUCTION

Water hyacinth and alligatorweed have become a grave problem in the South. Since their introduction into Louisiana in the latter part of the 19th century, these plants have established themselves in inland waters of all the South Atlantic and Gulf Coast States, and are invading the Tennessee Valley, Arkansas, and parts of California.

The hyacinth forms floating mats that cover ponds and sluggish streams. Alligatorweed not only forms similar mats, but invades marshy places, and is also able to grow on dry land. Floating weed mats hinder navigation, swamp logging operations, and oil development, interfere with agricultural drainage and irrigation, and create a public health problem. Coverage of open waters, and blanketing of marshlands by these weeds cause untold losses to wildlife and fisheries.

Control of these aquatic pests is a problem of tremendous proportions. Heretofore the U. S. Corps of Engineers has been the only agency able to carry on large-scale control operations. These operations are concerned mainly with the maintenance of navigable channels. State and private agencies have applied control measures at various times in the past without notable success. Growths at the heads of watersheds and in backwater swamps, lakes and marshes have not been reached by control measures previously employed, and these sources of reinfestation quickly nullify any clearance of adjacent waters.

A Resolution of the Committee of Rivers and Harbors of the House of Representatives, United States, adopted February 6, 1945, requested that the Board of Engineers for Rivers and Harbors review "the existing Federal Project for removal of the water hyacinth," and directed that the Fish and Wildlife Service of the Department of Interior, the Department of Agriculture, and the Public Health Service cooperate with the Board of Engineers in a joint investigation of the problem. In response to a request by the Secretary of War, August 8, 1945, the Secretary of Interior designated two representatives from the Fish and Wildlife Service. These representatives, Mr. Elmer Higgins and Mr. Arnold Nelson, attended the initial meetings of the several cooperating agencies, and accepted for the Fish and Wildlife Service responsibility for wildlife and fishery phases of the study.

Three specific assignments were given the Fish and Wildlife Service as follows: (1) Determine the exact nature and extent of wildlife and fisheries damage caused by weed infestation; (2) appraise the economic losses brought about by this damage; and (3) determine effects of weed control on wildlife and fisheries.

This report presents our summarized information in synoptic form so as to permit ready reference and use by engineers and others concerned with its immediate application in the control program. In addition two appendices are presented to record in some detail various biological information which would be lost by summarized treatment but which may be of interest to investigators concerned with additional ecological studies.

ORGANIZATION

Field Committees were set up in the South Atlantic, Lower Mississippi Valley, and Southwestern Engineer Divisions. Each Division Committee comprised representatives from the several cooperating agencies, with the Division Engineer or his representative acting as Committee Chairman. Each Chairman supervised the field studies in his Division, coordinated work of cooperators, and assumed responsibility for preparation of a Division Committee report.

The Fish and Wildlife Service named Mr. W. W. Anderson as its representative on the Lower Mississippi Valley and Southwestern Division Committees, and Mr. R. O. Smith on the South Atlantic Committee. These representatives attended the initial Division Committee meetings and a series of public hearings that were held subsequently by each Division for the purpose of gathering data on the extent and nature of the water weed menace.

The Service Water Quality Laboratories at Columbia, Missouri, immediately started a series of laboratory tests to determine whether new herbicides used for hyacinth control were toxic to fish. Results of these tests were reported on May 20, 1946. Further tests were reported jointly by Mr. Joseph E. King of the Service and Dr. William T. Penfound of Tulane University on May 20, 1946, and additional studies by Dr. James W. Moffett were reported on July 21, 1946.

Field investigations were inaugurated by the Service in June, 1946, under the supervision of Dr. Charles M. Mottley. Wildlife Biologist John J. Lynch, acting as field leader, maintained liaison among the various cooperators, coordinated Service field activities, and conducted certain wildlife studies. Earlier studies had already provided us with a large amount of data regarding effects of hyacinth and alligatorweed on wildlife. Further study was needed, however, on effects of new formagenic herbicides on wildlife food plants. These investigations were carried on in cooperation with Dr. Fred W. zurBurg of Southwestern Louisiana Institute, and Service personnel of the Lacassine and Sabine National Wildlife Refuges.

Aquatic Biologist Joseph E. King, stationed at New Orleans, was responsible for fishery studies in Louisiana. Biologist Arthur L. Smith was appointed to assist King in this work. Aquatic Biologist T. K. Chamberlain conducted fishery studies in Florida with headquarters at the Belle Glade Everglades Experiment Station. The fishery investigations were designed to show the reaction of fish and other aquatic life both to weed infestation and to masses of dead vegetation left by weed control operations. Many series of water-chemistry tests were made, accompanied where possible by live-box tests using both hatchery and native fish of all species.

ACKNOWLEDGMENT

Invaluable assistance has been rendered by the Federal agencies cooperating in this study, and by State and private agencies. Among the representatives of the Department of Agriculture, Mr. L. S. Evans helped materially in our Florida studies, Dr. William T. Penfound, offered data on the biology of water weeds, and Dr. Fred W. zurBurg assisted with chemical problems. The Department's Southern Regional Laboratory at New Orleans prepared reagents for water determinations. Dr. R. V. Allison, Director of the Everglades Experiment Station, assisted Mr. Chamberlain in every way, and made available to him the facilities of that Station. Mr. Thomas C. Erwin, Chemist at the Station, made the laboratory determinations of dissolved oxygen and hydrogen sulfide for the Florida work. Fishery studies of large-scale spraying with 2,4-D were possible through the kindness of Mr. Lamar Johnson, Engineer for the Everglades Drainage District. The Florida Commission of Game and Freshwater Fish furnished data on wildlife and fishery resources of Florida, and its wardens assisted in field operations. Major James Brown and Dr. James N. Gowanloch of the Louisiana Department of Wildlife and Fisheries supplied data on wildlife and fishery resources of that State, and reviewed our estimates on hyacinth damage to fishing waters. Mr. Percy J. Viosca, Jr. assisted in compiling fishery data. The South Atlantic, Lower Mississippi Valley, and Southwestern Divisions of the Corps of Engineers, and the various Districts under these Divisions, offered every assistance. Mr. William Wunderlich, Chairman of the Lower Mississippi Valley Division Committee, was particularly helpful in the work, and arranged for spraying operations in connection with fishery studies. The Shrimp Investigations Office in New Orleans, and the Federal Fish Hatchery at Natchitoches, Louisiana, both administered by the Fish and Wildlife Service, furnished office and laboratory facilities, automotive equipment, and fish for experimental purposes.

REPORT OF FINDINGS

This report presents the findings of the Fish and Wildlife Service with regard to: (1) The nature and extent of damages caused by obnoxious weeds to wildlife and fisheries; (2) the economic losses brought about by this damage; and (3) the effects of mechanical and chemical weed control on wildlife and fisheries. Other phases of the water weed problem, such as the history and extent of infestation, biology of the plants, control methods, and public health significance, have been investigated by the U. S. Engineers, the Department of Agriculture, and the Public Health Service.

I. Specific Effects of Weed Infestation on Wildlife and Fisheries.

A. Wildlife.

Although this investigation is concerned primarily with the water-hyacinth, the Congressional Resolution authorizing the study directed also that "other marine vegetable growths" be considered. We wish to point out, therefore, that alligatorweed can be as serious a menace to wildlife as the water hyacinth, and thrives in certain brackish muskrat and waterfowl marshes where hyacinth is unable to survive. Both plants are primarily responsible for the damages reported here, but certain other plants are detrimental to wildlife in varying degree. Among these are water primrose (Jussiaea), and lotus (Nelumbo) in Louisiana and Texas; water lettuce (Pistia), cow-lily or bonnets (Nuphar), and pickerelweed (Pontederia) in Florida, and several submerged aquatics such as bladderwort (Utricularia), coontail (Ceratophyllum), waterweed (Heteranthera), milfoil (Myriophyllum), and Cabomba. These plants have limited value for wildlife, and compete with more useful plants in addition to obstructing navigation.

1. Ecological effects of infestation.

a. Direct effects.

Hyacinth, alligatorweed and other waterweeds rarely cause immediate destruction of wildlife, since birds and mammals are able to move out of infested areas.

b. Effects on wildlife habitat and foods.

Hyacinth and alligatorweed can utterly destroy wildlife values of the following types of habitat by blanketing open water and overwhelming food plants. Unfortunately these plants thrive best in rich waters that are most productive of wildlife. The native vegetation of these waters is unable to compete with the exotic invaders.

(1) OPEN LAKES. Valuable mainly for diving ducks such as canvasbacks and scaup. Hyacinth and alligatorweed may not completely cover large lakes, but drifting mats tear up beds of submerged plants, and defoliate floating-leaved aquatics such as banana waterlily, a very valuable canvasback food. High winds jam drift hyacinth mats against lake shores, overwhelming marginal duck foods such as smartweeds, bulrushes, and duck potato.

(2) PONDS AND RECLAMATION LAKES. Important as rest areas for all ducks, and preferred feeding grounds for ringneck and ruddy ducks, pintail, gadwall, baldpate and scaup, and pond coots. Hyacinth will in time completely cover ponds, ruining them for wildlife. Partial coverage by weeds likewise is serious, since weed mats that may cover only 1/10 of a pond will drift over remaining open water with changing winds, destroying duck food plants by occluding sunlight, increasing turbidity, and uprooting. Drift mats of hyacinth, and shore growths of alligatorweed preclude growth of desirable marginal vegetation. This depletion of foods not only lowers waterfowl value of ponds, but also aggravates competition between ducks and coots for remaining foods.

(3) MARSH SWALES. Many of our fresh and slightly bracking marshes are valuable for waterfowl only when well supplied with openings in their dense vegetation. Such openings are attractive to mallards, pintail, teal, and canada and white-fronted geese. Wading birds, and fur-bearers such as mink, raccoon and otter also favor swale ponds. Hyacinth, alligator-weed and water primrose blanket such areas, often within a year after introduction, destroying all wildlife foods.

(4) SLOW STREAMS, CANALS, AND BORROWPITS. These are used chiefly by wood ducks and a few divers, and certain fur animals. Wildlife values of these waterways are not particularly high, but hyacinth and alligatorweed infiltrate through them and spread into adjacent ponds, swamps and marshes with every high water.

(5) SWAMPS AND SWAMP LAKES. Timbered swamps are valuable for wood ducks, and swamp lakes are utilized by all swamp ducks including the mallard. Logging removes the tree canopy of swamps, and immediately a rich ground flora, including duck potato, grasses and sedges, and a brush understory including such duck foods as button-bush, water elm and water pivet develops. Damming of swampy streams likewise opens the tree canopy by drowning some timber. Unfortunately this same factor that permits development of wildlife foods also makes possible the spread of hyacinth. Once the latter moves into a swamp that has been opened up by logging or flooding, all wildlife benefits are immediately nullified.

(6) FLOOD-BOTTOMS. These are utilized by mallards, particularly at times when the bottomland oaks produce a heavy acorn crop. Deer, turkey, woodcock, and other forms of wildlife also are found here. Spring floods move hyacinth into flood-bottoms. These plants become stranded by subsequent low water, but often remain alive in wet depressions that otherwise would be valuable for waterfowl and woodcock.

(7) THE FRESH MARSHES. The fresh marshes of the Mississippi Delta are valuable for geese, ducks and muskrats. The maidencane (Panicum) marshes of Terrebonne and Lafourche Parishes produce a large crop of muskrats, and a similar marsh type in southwest Louisiana and Florida is attractive for waterfowl. Hyacinth grows only in openings in the fresh marshes, but alligatorweed can invade certain of these marshes and destroy them for muskrats and waterfowl. Alligatorweed has brought about the loss of much of the marsh of the Mississippi Delta by preventing proper trapping of muskrats. Untrapped rats eventually overpopulated their habitat, used up what food plants had survived the infestation, and then as a last resort undermined all other remaining marsh vegetation including the Roseau Cane (Phragmites). Much of this land is now solid alligatorweed, and worthless for muskrats.

(8) THE BRACKISH MARSHES. These are famous for their contribution to Louisiana's $15,000,000 annual fur crop, chiefly muskrats. They are important likewise for blue and snow geese and many species of ducks and shorebirds. Alligatorweed, which has a higher tolerance for salt than the other weeds in question, is now invading small openings in brackish marsh, thereby destroying them for ducks. When it invades the marsh proper, it will kill off the foods of geese and muskrats.

c. Interference with Natural Maintenance of Wildlife Habitats.

Aquatic environments are constantly changing. When left undisturbed for long periods, their vegetation follows a successional pattern that culminates in a grassland or tree climax. Our coastal marshes are most productive of wildlife in their lower successional stages. In climax, the wildlife food plants of the latter are obliterated.

(1) Nature periodically subjects climax vegetation to drastic treatment. Prolonged floods, hurricane tides, and severe droughts with attendant fires all serve to remove worthless climax plants. Valuable wildlife plants are quick to recover, and while wildlife may have suffered during the floods or droughts, it is benefited greatly in the long run by improvements in its habitats.

(2) Floods and storm tides also distribute hyacinth and alligatorweed. Here we have an anomalous situation that becomes more noticeable every year. The natural factors that bring about improvements in habitats are spreading the weeds that destroy these improvements.

(3) Alligatorweed mats that float down the coastal rivers are picked up by Gulf tides and thrown over the low beaches of south Louisiana. As a result, this plant, which is able to survive for several weeks in the shore waters of the Gulf, is spreading into valuable wildlife marshes along the coastal strip.

d. Interference with Habitat Management.

Improvement of marsh lands for waterfowl and fur animals is one of the primary aims of wildlife refuges, hunting clubs, and fur ranchers. This is achieved by means of food-plantings, creation of ponds, water control, and maintenance of channels and boat trails.

(1) Hyacinth and alligatorweed take over ponds as fast as they are created, overwhelm food-plantings, and generally defeat all efforts to improve wildlife habitat. It should be remembered that many management measures that improve a marsh for wildlife also render it more susceptible to weed infestation.

(2) This situation is now so acute in some regions that marsh operators have suspended all improvement work until weed control can be assured.

e. Effects upon Concentration and Hunting Pressure.

All waterfowl must have rest areas as well as feeding grounds. Hyacinth and alligatorweed are encroaching upon and destroying both to an alarming degree.

(1) As destruction of feeding grounds progresses, waterfowl overconcentrate on remaining open areas, depleting their food supply.

(2) Pond coots, which arrive on the Gulf Coast in early autumn, also congregate on remaining open areas, and may use up all waterfowl foods before the winter flights of ducks arrive.

(3) Overconcentration on feeding grounds leads to disproportionate early kill each hunting season. Overconcentration on a few rest areas invites illegal shooting and market hunting. Result is the destruction of many waterfowl, and complete exodus of wildlife that might have furnished sport for legitimate hunters throughout the season.

(4) Overconcentration of any form of wildlife favors spread of parasitism and diseases.

f. Beneficial effects of weeds.

Any wildlife benefits that might be produced by hyacinth and alligatorweed are insignificant when compared with the harmful effects of weed infestation.

(1) Hyacinth is absolutely worthless for wildlife. No part of the plant is used as food by waterfowl or fur animals. The claim has been made that hyacinth jams saved ducks by preventing hunters from getting to their more isolated habitats. This might be true in some instances, but the opposite is the case when hyacinth destroys these isolated habitats and forces ducks to move into areas where they may be killed with ease.

(2) Alligatorweed is eaten by canada geese and some ducks, and by marsh deer and a few furbearers such as nutria (coypu). This occurs mainly in late winter when there is little other green vegetation available. It cannot be said that the plant is beneficial to wildlife, since this slight contribution to the food supply of a few species is insignificant when compared with the damage caused by alligatorweed to wildlife habitats and native foods.

2. Effects upon Wildlife Utilization.

a. Law enforcement.

Strict enforcement of game laws is essential if we are to maintain adequate breeding stocks of game birds and mammals.

(1) Hyacinth jams prevent wardens from patrolling remote swamps and marshes.

(2) Market hunters, who live in such areas, can destroy large quantities of game without fear of retribution.

b. Interference with hunting.

Hyacinth and alligatorweed ocver shooting ponds, destroy duck foods, and seriously hinder boat operations.

(1) The following figures give some idea of the importance of waterfowl in the South.

(a) Louisiana: Each year 42,000 waterfowl hunters kill an average of 1,195,253 waterfowl. A yearly cash value of $5,976,265 is placed on this wildlife crop.

(2) Hunting clubs are forced to spend thousands of dollars each year on aquatic weed control. Small clubs that cannot afford control go out of business.

(a) Louisiana: One club at Morgan City, three near New Orleans, and three in Cameron Parish are facing complete loss of their shooting ponds due to hyacinth. Only 8 small ponds can now be hunted on the State Public Hunting Grounds at Pass a Loutre; the remainder of this 60,000 acre tract is blanketed by hyacinth and alligatorweed.

(3) Free-lance duckhunters can no longer reach many of their former hunting grounds due to blockage of streams and lakes. The swamp lakes of the Atchafalaya Basin in Louisiana are an outstanding example.

c. Interference with trapping and alligator hunting.

Hyacinth blocks channels and pirogue trails. Alligatorweed is moving into the muskrat marshes, and threatens to destroy many valuable marshes.

(1) As much as $15,000,000 worth of fur and hides is produced annually by the marshes of Louisiana. Hyacinth is threatening this industry by blocking channels and trails, especially in the floating marshes of Terrebonne, LaFourche, and Plaquemines that can be trapped only from pirogues.

(2) Hyacinth now covers many lakes that formerly produced a large crop of alligators.

(3) Alligatorweed is tying up boat operations in some brackish marsh channels, and is spreading into these marshes with every high water, destroying the land for muskrats.

(4) An estimated 5 per cent of Louisiana's muskrat marshes, mostly on the Mississippi Delta, has already been completely destroyed by alligatorweed and hyacinth. It is estimated that the quarter-million muskrats this land formerly produced would have been worth $312,000 annually. Land values lost in this case amount to $500,000.

d. Cumulative loss of investments.

Agencies and individuals have a considerable investment in wildlife conservation and utilization. When weeds destroy an area for wildlife, all investments in that area are lost.

(1) In Louisiana, 15 large private and commercial hunting clubs have a total annual investment of $63,525, and about 60 small clubs have $30,600 so invested.

(2) Louisiana's 15,000 trappers have an estimated $4,500,000 annual investment in the tools and equipment of their trade.

(3) In Louisiana, Federal, State and private agencies have a grand total of $3,589,925 invested in lands and improvements for wildlife refuges, hatcheries, etc.

e. International significance of waterfowl.

Waterfowl that frequent the Gulf Coast States furnish hunting for the Canadian Provinces, a large portion of the United States, Mexico and Central America. Since hyacinth and alligatorweed destroy the feeding and wintering grounds of these migratory birds, control of these weeds can be considered a national and international problem.

(1) The Mississippi Flyway: Ducks and geese from the Arctic regions and central Canada migrate from there down the Mississippi Valley. It is estimated that 20,000,000 of these winter or stop en route in Louisiana's waters.

(2) The Central Flyway: About 2,500,000 waterfowl from the Mississippi Flyway and also from the Plains States and Prairie Provinces of the Central Flyway, winter on the Texas Coast in regions susceptible to hyacinth and alligatorweed infestation.

(3) Florida's fresh waters harbor over a million ducks from the Atlantic Flyway.

B. Fisheries.

1. Ecological Effects upon Fish Life.

a. Direct effects.

Hyacinth and other floating weeds can bring about destruction of fish under some circumstances.

(1) Hyacinth and other floating weeds exhaust the dissolved oxygen in waters they cover.

(2) Some fish can get by on small amounts of dissolved oxygen for a time, provided they have access to open water. Once a lake becomes completely covered, all game and pan fish must eventually perish.

(3) When backwaters of a watershed become covered with hyacinth, the fish are driven to what open channels remain. During summer low water, drainage from these oxygen-depleted backwaters finds its way to channels, and often causes large-scale kill of fish therein.

b. Effects upon habitat.

Five different types of fishery waters occur in the South. Hyacinth and alligatorweed can damage all types, and permanently destroy some.

(1) Borrow-pits. Along all highways that transect swamps and bottomlands, and coastal marshes. These are important for food-fishing, frogs and turtles. Many contain game fish, which may be caught by anglers or seined by conservation agencies for restocking other waters. Complete coverage of borrow-pits by hyacinth and alligatorweed destroys fish, and over a period of time will cause filling and conversion to marsh.

(a) Louisiana's hundreds of miles of deep borrow-pits are about 95 per cent infested, and 15 per cent are now permanently lost.

(2) Canals. While their primary purpose is drainage, irrigation and navigation, they furnish sport and commercial fishing, crabs, frogs, turtles, and eels. Louisiana's canals are about 45 per cent infested, and 5 per cent so badly filled that they need dredging.

(3) Streams. These are important for sport fishing and recreation, and for commercial fisheries, including frogs, crawfish, crags and turtles. Present infestation in Louisiana and Florida about 35 per cent.

(4) Ponds and lakes. These produce the bulk of the South's game and pan-fish, as well as an important commercial fishery. About 25 per cent of Louisiana's lakes are badly infested at present, and about 3 per cent totally lost. The majority of Florida's 30,000 lakes are susceptible to hyacinth, and many are already damaged beyond utilization.

(5) Reclamation lakes. About 35 in southeastern Louisiana. All are infested in varying degree, and about 20 per cent of their former area has already been converted to floating marsh. All will be filled or converted to marsh within the next 30 years if hyacinth is not controlled.

c. Effects upon fish predation.

The gar is the most serious enemy of southern game fish. Hyacinth infestation often favors survival of gars while hastening destruction of game and pan-fish.

(1) As a lake fills with hyacinth, game and pan-fish congregate in remaining open water where there is ample dissolved oxygen.

(2) Gars frequent these openings, and destroy all game and pan-fish except the small fingerlings that can hide in the hyacinth mats.

(3) Gars are able to breathe air, and thus are the last fish in infested waters to be hurt by encroaching hyacinth.

d. Effects on food-chains.

Game and commercial fish prey on smaller fish, insects, etc. that in turn live on more minute aquatic organisms. Hyacinth interferes with normal operation of this fish "food chain."

(1) Hyacinth, by excluding sunlight and using up dissolved nutrients, retards production of micro-organisms.

(2) Hyacinth blankets out the submerged plants that ordinarily would harbor aquatic organisms.

(3) The root system of the hyacinth plant is an admirable hiding place for aquatic organisms. This leads some fishermen to believe that hyacinths benefit fish life. We find that the individual hyacinth plant will harbor more fish

food than any native plant. Once a solid mat has formed, however, only those plants at the very edge of the mat will harbor significant quantities of organisms.

(4) Minnows and other fish foods are protected by matted hyacinth to such an extent that often larger fish are unable to use them as food.

e. Effects on spawning.

Game and pan-fish may drape their eggs on submerged vegetation or deposit them in scrupulously cleaned beds on lake-bottoms.

(1) Stationary hyacinth mats ruin spawning areas by covering beds with detritus.

(2) Free-floating mats may be drifted over beds during spawning seasons, destroying all eggs and some spawning fish.

(3) Submerged vegetation that furnished spawning grounds for some species is destroyed when covered by hyacinth.

f. Effects on lake balance.

The best fishing lakes are those in which game fish, pan-fish, coarse fish, and their respective food organisms occur in proper proportions. Such lakes are said to be "healthy," or "in balance." Hyacinth very often upsets this balance.

(1) Advanced hyacinth infestation, by destroying game and pan-fish without immediately hurting gars, upsets balance in favor of predators.

(2) Destruction of shoal-water spawning grounds by hyacinth will cut bass production radically, but bream and other pan-fish that are able to spawn in deeper water continue to survive and increase. In a few years only large bass will survive, since the overabundant bream will eat what few bass eggs are spawned. Furthermore these surviving large bass will not take a bait or lure, since they have a superabundance of natural foods.

(a) Florida: Lake Trafford, one of the State's most famous bass lakes, is now out of balance due to hyacinth.

(b) Louisiana's reclamation lakes and many natural lakes are similarly out of balance.

(3) Spread of hyacinth in a lake brings commercial fishing to a halt long before sport fishing goes out. Thus gars and other coarse fish that might have been kept under control

by commercial fishermen are allowed to increase while game and pan-fish are reduced by fishing and predation. The obvious result is a "sick" or out-of-balance lake.

g. Possible effects upon salt water fisheries.

The coastal marshes produce many of the food organisms that are essential for salt water fish, crabs, shrimp and oysters. It is not possible to say just how weed growths in these marshes affect marine fisheries of adjoining coastal bays. It is known, however, that hyacinth and alligatorweed remove oxygen from water, and discourage micro-organisms that would otherwise furnish fish food. Furthermore, instances have been witnessed where fish and crabs were destroyed by decaying mats of salt-killed alligatorweed. It is suspected that alligatorweed, that invades coastal brackish marsh during years of abundant rainfall and is killed by subsequent salt tides, may be an important factor in the salt water fisheries of the coastal bays.

2. Effects on Utilization of the Fisheries.

a. Sport fishing.

Where hyacinth and alligatorweed block streams and lakes, and form jams around boat-landings, fishing and boating cease.

(1) Sport fishing in southern fresh waters affords recreation for hundreds of thousands of anglers.

(a) Florida: License sales show 73,282 resident anglers and 18,899 tourist fishermen.

(b) Louisiana: In 1945 issued 25,120 licenses to resident anglers, and 6,848 to non-residents.

(2) Tourist fishing is now a highly commercialized business in Florida and parts of Louisiana.

(a) Florida: 307 fishing camps listed by the State Game and Fish Commission have 625 cabins and 2112 boats. It is estimated that these camps represent an annual investment of $1,050,000.

(b) Louisiana: 15 large and 60 small combination hunting and fishing camps, and about 100 fish-camps have a combined annual investment of $364,125.

b. Cane-pole fishermen.

Most southern States do not have or require a license for cane-pole fishing. There is, therefore no source of definite figures, but it is estimated that there are a quarter million people in the Gulf Coast States engage in cane-pole fishing for enjoyment and food.

(1) City-dwellers and country folk, young and old, enjoy cane-pole fishing in canals and ponds close to home. Many of these people could not afford expensive sport-fishing tackle.

(2) Cane-pole fishing is a serious business to thousands of negroes and poor whites. In hard times these people depend on pan-fish and coarse fish for food.

(3) The cane-pole fisherman has been hardest hit by hyacinth and alligatorweed. The roadside borrow-pits, canals and small ponds they fish are most susceptible to weed infestation, and will be destroyed in time if weeds are not controlled.

c. Interference with commercial fisheries.

Hyacinth and alligatorweed interfere with all commercial fresh-water fisheries.

(1) These fisheries are an important business in the southern States.

(a) Louisiana: Approximately 5,000 commercial fishermen catch 20,000 pounds of fresh-water fish per year, worth about $7,600,000. It is estimated that their annual investment in boats, gear and shore plants amounts to $1,566,803.

(b) Florida licenses 1,040 retail and 340 wholesale outlets for its fresh-water commercial fisheries products.

(2) Blockage of streams and canals prevents fishermen from getting to their fishing waters, and may so delay boats that catches spoil before they can be gotten to icing plants or markets.

(3) Moving hyacinth and alligatorweed mats tear up set-lines, nets, traps, and other fishing gear. Seining is an utter impossibility in hyacinth-filled waters.

(4) In parts of Louisiana, shrimp, oyster, and salt-water fishing boats operate from landings along coastal streams and bayous. Hyacinth and alligatorweed, floating down from inland, have tied up Gulf fishing boats for days at a time in the Lafourche-Terrebonne section of the State.

II. <u>Results of chemical and mechanical weed control on wildlife and fisheries</u>.

A. <u>Wildlife</u>.

1. <u>Immediate results</u>.

a. <u>Direct effects on birds and mammals</u>.

None was observed. All wildlife leaves the scene when spraying or mechanical operations are in progress.

(1) Arsenical sprays are potentially dangerous to all wildlife, particularly deer and other animals that might eat out sprayed vegetation.

(2) Formagenic sprays (2,4-D), no ill effects were observed. Cattle and probably deer relish sprayed vegetation. Ducks and wading birds often seen feeding in sprayed hyacinth.

b. <u>Effects on food and cover plants</u>.

While few wildlife plants are found in hyacinth and alligatorweed mats, plane sprays and dusts may drift onto adjacent stands of valuable food plants.

(1) Experiments show that 2,4-D sprays of standard concentration (1000 ppm) in water solution killed only three of 40 important species of wildlife food plants. Oil sprays are more toxic, but do not completely kill perennial plants unless heavy application is made. Water primrose (<u>Jussiaea</u>), a pest plant, proved very susceptible, being killed by 100 ppm.

c. <u>Reaction of wildlife to decaying plants</u>.

Most forms of wildlife shun treated areas during the period of active decomposition, which may last for 2 months in static waters, but only a few weeks where there is current or wave action.

2. <u>Ultimate results</u>.

a. <u>Habitat changes</u>.

If the hyacinth is killed before acute infestation occurs the area may be returned to useful productivity in a relatively short time. Where the hyacinth has persisted over a period of years, some lasting effects occur.

(1) Where mats have persisted for years, a thick floating turf will be found underlying the surface mat. Kill of hyacinth in this case speeds establishment of cattail, sedges, duck potato and smartweeds. These new plants convert the old mat into floating marsh, thus the area may be permanently lost for fishing purposes.

(2) Even if this floating debris is swept away by wave action, the bottom ooze deposited by the former mat may retard growth of submerged aquatics for several years.

(3) It should be remembered that these after-effects are the result of the original infestation, rather than of control.

b. Comparative benefits.

Not a single instance has been observed where weed control damaged wildlife habitat any more than did the original infestation.

(1) Chemical and mechanical destruction of hyacinth may contribute to ooze deposits, but over a period of time this contribution is negligible compared with the steady deposit laid down by living and winter-killed plants.

(2) It is believed that the sooner control of the infestation is started, the less the undesirable after-effects will be.

B. Effects of Weed-control on Fisheries.

1. Immediate effects.

a. Toxicity and injury to fish.

Mechanical control and 2,4-D sprays are not seriously harmful to fish. Arsenicals and Benoclors are toxic.

(1) Bream and other small fish will jump out of hyacinth mats ahead of a sawboat, and become stranded on the shredded plants. This loss is not significant.

(2) Arsenical sprays may be injurious to animal life including livestock and are dangerous to humans.

(3) The benoclors, used for controlling submerged plants, are toxic to fish in concentrations usually employed for weed control.

(4) 2,4-D is non-toxic to fish in concentrations usually employed for hyacinth control. Laboratory experiments conducted by Ellis, Westfall and Jones, and additional studies by Moffett, Bender and Davenport of the Fish and Wildlife Service, show that 2,4-D in concentrations less than 100 ppm is harmless to fish. Higher concentrations will kill some fish, and 1000 ppm killed all species studied. Calculations by the Florida Citrus Experiment Station and by King of the Fish and Wildlife Service show that normal spraying of hyacinth with 2,4-D is unlikely to cause concentrations of the chemical in underlying water greater than 1 ppm.

b. Immediate effects on water chemistry.

The amount of dissolved oxygen in waters under sprayed or shredded hyacinth remains very low, 1 to zero ppm, until large patches of open water appear.

(1) While this figure is insufficient to support fish life, it must be remembered that dissolved oxygen under living hyacinth is rarely over 1 ppm.

(2) Products of plant decomposition, such as methane and hydrogen sulfide, are toxic to fish in high concentrations. In the case of hyacinth, however, only the rhizome, a relatively small part of the plant, is subject to immediate decomposition. Remaining portions, made up largely of cellulose and water, sink to the bottom, where they disintegrate so slowly that there is little chance of the release of gases in toxic amounts, or the production of an unusually high oxygen demand.

(3) It is significant that no one has reported large numbers of fish killed by hyacinth control operations. It is known that conditions under dying hyacinth are unfavorable for fish. The same conditions prevailed prior to treatment, however, so it is logical to assume that the reason no fish were killed by control measures is that no fish were present at the time.

c. Duration of danger periods.

Conditions unsuitable for fish may last for only a few days, or may persist for as long as two months under sprayed or shredded hyacinth.

(1) Current in streams, and wind and wave action in large lakes will open up dying hyacinths within two weeks, and give surviving fish access to oxygenated water.

(2) In static waters, dissolved oxygen remains very low even after openings appear. In Hamburg Lake in Florida, dissolved oxygen was still less than 1 ppm two months after open water appeared. It is suspected that this was caused by the high oxygen demand of large quantities of suddenly killed

rhizomes following the sawboat operation. Open water usually appears sooner in mechanical control than after spraying, giving fish immediate access to the better-oxygenated surface layer of water.

(3) Dissolved oxygen may remain low in static waters under sprayed hyacinth for as long as 2 months, or until rhizome decomposition is completed and other portions of plants have sunk or drifted to shore.

(4) Regardless of the method of control or the duration of the danger period, the survival of fish in a given body of water is determined by the amount of infestation and the distribution of fish at the time control operations were begun.

d. Progressive weed control.

Treatment of an infested lake by stages will return it to productivity with the least danger to fish life.

(1) Hyacinth control was started in one Florida lake just as infestation was nearly complete. Portions of the hyacinth mat were sprayed every few weeks until complete kill was achieved. This created openings where fish could survive while other parts of the mat were treated. At no time was any great amount of decaying material in the lake.

(2) This method might be employed by private owners of small lakes, but is impractical for large-scale operations. Furthermore, it is uneconomical, since the untreated hyacinths spread while treated areas are dying.

e. Fish-kills not associated with weed control.

Sudden large-scale fish-kills occur every year in Louisiana and Florida. Although these may or may not be associated with hyacinth, they could occur in the course of weed-control operations. The casual observer would immediately blame weed control for the loss of fish.

(1) Fish-kills in the Florida Everglades may be caused by hydrogen sulfide that is carried into canals and streams in rain waters draining out of reclaimed muck soils. Concentrations of 40 ppm of hydrogen sulfide in canal waters of this region were recorded. A mere 5 ppm of this gas is known to be toxic to some fish. Hyacinth infestation or control has nothing to do with this phenomenon, although hyacinth could aggravate it by denying fish access to the water surface.

(2) Backwater swamps in the Atchafalaya Valley and the Florida Everglades drain into streams and lakes at times of low water. This swamp drainage water is usually low in

dissolved oxygen and high in dissolved gases that are toxic to fish, and its sudden introduction into streams may result in fish-kill. This can occur even if no hyacinth is present in the backwaters, but live or decaying hyacinth will aggravate the condition.

2. <u>Ultimate results of weed control</u>.

a. <u>Time required for treated areas to return to normal</u>.

Water conditions become favorable for fish as soon as the water surface is cleared of hyacinth and dissolved oxygen returns to 3 ppm.

(1) Current and wave action may clear streams and large lakes in a few weeks. Static waters usually do not clear in less than 2 months after treatment.

(2) With return of normal water conditions, fish that survived infestation and control are out of danger.

b. <u>After-effects</u>.

Bottom deposits, turbidity, and other after-effects may persist for years.

(1) Bottom ooze and hyacinth debris may cover spawning beds for long periods after successful weed control. This ooze also causes extreme turbidity in shallow water, preventing re-establishment of submerged vegetation.

(2) Bottom detritus will float to the surface in warm weather for years after kill of hyacinth. This material does not have the high oxygen demand that might be suspected, but may cause damage by drifting over spawning grounds.

(3) Hyacinth infestation, rather than control, is responsible for these after-effects. They can be minimized by control of hyacinth before infestation becomes widespread.

c. <u>Suggestions for fisheries rehabilitation following weed control</u>.

Waters that suffered prolonged hyacinth infestation may require restocking or other treatment before they can be returned to productivity.

(1) Any badly infested lake is apt to be out of balance. It may have too many predacious fish, too many pan-fish, or too many large game fish. Study of surviving fish populations, and seining of surplus fish may be necessary before restocking is attempted.

(2) Hatchery fish can survive in a treated lake five months after complete eradication of hyacinth.

(3) Before any restocking is attempted, its need and chances for success should be determined. Streams and overflow waters will return to balance in many cases without human intervention. Fish populations in some lakes will do likewise. Each water body will have its peculiar problems, and any rehabilitation work following hyacinth eradication must be guided by the solution to these problems.

III. Dollar-value of Wildlife and Fishery Losses Caused by Weed Infestation.

The recreational values of wildlife and fisheries are intangible and cannot be easily reduced to figures. Such values are reflected to some extent in the dollar-values per unit of game birds, mammals and fish, since these figures represent the total value of the unit when harvested.

Values were computed for the wet-lands of Louisiana, and for the freshwaters of Florida. The per-acre figures for the former are applicable to weed-infested waters of Louisiana and Texas. The Florida figures apply to all the South Atlantic States where the weeds have become established. In order to evaluate the damages caused by weed infestation it is necessary to determine the total value of wildlife and fishery resources of a region.

A. Annual Crop Value of Wildlife and Fisheries.

1. Methods of computing yields and values.

a. Hunting. Annual kill of waterfowl and other wildlife has been averaged from published reports of State Conservation Departments and original estimates. Value per unit is taken from standard figures developed by the Office of River Basin Studies, Fish and Wildlife Service. These figures reflect the costs involved in bringing the unit to bag.

b. Trapping. Annual catch averaged from State records. Average prevailing prices for raw hides determine value of unit.

c. Sport fishing. Yield in pounds per acre has been estimated on the basis of known catch records for various types of fishing waters. Thus it is estimated that fresh water in Louisiana (2,000,000 acres) annually yields 10 lbs. of game and panfish per acre, including bass and other fish that are taken on artificial lures, panfish that are caught by pole fishing, and various fish, frogs, turtles and crawfish that are taken for food or sport but not for sale or market. Value per unit is based on the River Basin manual, except for Florida bass, which have higher value due to the tourist fishery of that State.

d. Commercial fishing. Total catch records from State and Federal Bulletins, particularly Federal Fisheries Surveys. Value per unit based on normal retail market prices.

2. Annual average value of Wildlife and Fisheries, crop, Louisiana. (Computed for habitat types susceptible to weed infestation, see tables 1 to 5, inclusive, under C. below.)

Habitat type	Acreage	Total annual yield	Value per acre
Swamp	1,500,000	$ 2,640,000	$ 1.76
Fresh water	2,000,000	31,350,000	15.67
Fresh marsh	1,750,000	4,855,000	2.77
Salt marsh	2,500,000	85,603,906	34.24

3. Annual average Value of Wildlife and Fisheries crop, Florida.

Waterfowl, 200,000 at $5.00	$ 1,000,000
Fur and hides (State records)	40,000
Bass, 10,000 lbs. at $3.00	30,000,000
Panfish, 27,500,000 lbs. at $.75	20,625,000
Commercial fish (est. 5,000,000)	1,500,000
Total	$53,165,000

Acres freshwater - 2,500,000
Value per acre of freshwater - $21.27

B. Annual Crop Losses Caused by Weed Infestation.

1. An acre of land completely covered by hyacinth or alligator-weed destroys all wildlife and fishery values that land may have had prior to infestation. This loss is computed on the basis of prior wildlife and fishery crop values for that particular acre. Total crops lost due to direct infestation are listed under "Crops totally destroyed."

2. This same acre of weeds may so block a waterway that hundreds of acres of hunting and fishing waters beyond the block, while not infested by weeds themselves, cannot be reached by hunters and fishermen for long periods each year. Thus the wildlife and fishery crops that these waters might yield cannot be harvested to their fullest extent. These potential crops, particularly fisheries, are lost if not harvested. This loss is chargeable to the weed infestation that made harvest impossible. The number of acres so affected are estimated for each habitat type. It is considered that their potential annual yields have been reduced by approximately one-half. Values lost are obtained by multiplying the number of acres by half the annual crop value per acre.

3. Computation of the Wildlife and Fishery Annual Crop Losses Caused by Weed Infestation.

Habitat type	Annual Crops Totally Destroyed			
	Crop values	Acres of weeds	Crop value per acre	Loss
Louisiana				
Swamps	$ 2,640,000	75,000	$ 1.76	$ 132,000
Fresh water	31,350,000	200,000	15.67	3,134,000
Fresh marsh	4,855,000	200,000	2.77	554,000
Salt marsh	85,603,906	25,000	34.24	856,000
Total	$124,448,906	500,000		$4,676,000
Florida				
Fresh water	$53,065,000	150,000	$21.27	$3,190,500

Habitat type	Annual Crops Affected By Blockage		
	Acres Affected	Crop value per acre	Annual Loss
Louisiana			
Swamps	500,000	$ .88	$ 440,000
Fresh water	500,000	7.83	3,915,000
Fresh marsh	400,000	1.39	556,000
Salt marsh	300,000	17.12	5,136,000
Total	1,700,000		$ 10,047,000
Florida			
Fresh water	200,000	10.63	$2,126,000

Louisiana - Grand total of Losses, crops destroyed and not utilized	$14,723,000
Florida - Grand total of Losses, fresh water crops.	$5,316,500

C. Tables of Supporting Data.

Tables 1 to 5, inclusive, contain the basic data from which the dollar-values have been computed. Tables 6, 7, and 8 supply data on some of the investments made for harvesting wildlife and fish crops.

Table 1. Classification of wet lands, Louisiana.
(Viosca; Flood bottoms not included in data, only permanent water areas.)

Acreage	Swamp	Fresh water	Fresh marsh	Salt marsh	Total
Total acreage	1,500,000	2,000,000	1,750,000	2,500,000	7,750,000
Acreage susceptible to weed infestation	1,000,000	1,000,000	1,750,000	1,000,000	4,750,000
Acreage now infested	75,000	200,000	200,000	25,000	500,000
Acreage rendered inaccessible for periods by weed blocks in channels resulting in low yields.	500,000	500,000	400,000	300,000	1,700,000

Table 2. Wildlife and fishery values, Swamp habitats, Louisiana.

Item	Total populations and values			Annual crop value		
	Number	Unit value	Total value	Kill	Unit value	Total value
Swamp deer	10,000	$100.00	$ 1,000,000	1,000	$100.00	$ 100,000
Squirrel	300,000	1.50	450,000	100,000	1.50	150,000
Rabbits	1,000,000	1.00	1,000,000	500,000	1.00	500,000
Mink	300,000	8.00	2,400,000	80,000	8.00	640,000
Raccoon	400,000	2.00	800,000	100,000	2.00	200,000
Woodcock	200,000	5.00	1,000,000	10,000	5.00	50,000
Ducks	7,000,000	5.00	35,000,000	200,000	5.00	1,000,000
Total			$41,650,000			$2,640,000
Value per acre (1,500,000 acres)						
	Total populations		$27.76		Annual Crop	$1.76

Table 3. Wildlife and Fishery Values, Freshwater bodies, Louisiana

Unit	Total populations and values			Average annual crop values		
	Number (pounds)	Unit value	Total value	Kill (pounds)	Unit value	Total value
Ducks	5,000,000	$5.00	$ 25,000,000	400,000	$5.00	$ 2,000,000
Coots	2,000,000	1.00	2,000,000	500,000	1.00	500,000
Game fish	20,000,000	2.00	40,000,000	5,000,000	2.00	10,000,000
Panfish	50,000,000	.75	37,500,000	15,000,000	.75	11,250,000
Comm. fish	30,000,000	.30	9,000,000	12,000,000	.30	3,600,000
Frogs, etc.	20,000,000	.50	10,000,000	8,000,000	.50	4,000,000
Total			$123,500,000			$31,350,000
Value per acre (2,000,000 acres)						
	Total populations		$61.75	Annual crop		$15.67

Note:--River Basin values used for sport hunting and fishing; retail values for commercial fisheries which include (based on State data) nearly 20,000,000 lbs. of commercial fish, of which 6/10 are food fishes, valued at $.30/lb., and 4/10 are frogs, turtles, crawfish, etc. valued at $.50/lb.

Table 4. Wildlife and Fishery Values, Fresh marsh, Louisiana.

Unit	Total populations and values			Average annual crop values		
	Number (pounds)	Unit value	Total Value	Kill (pounds)	Unit value	Total value
Ducks	4,000,000	$5.00	$20,000,000	300,000	$5.00	$1,500,000
Snipe	300,000	5.00	1,500,000	15,000	5.00	75,000
Rails	1,000,000	1.00	1,000,000	200,000	1.00	200,000
Fur animals	est.		6,000,000	1/3 of State total		3,080,000
Total			$28,500,000			$4,855,000
Value per acre (1,750,000 acres)						
	Total populations		$16.28	Annual crop		$2.77

Note:--Snipe presently protected, but have been on game list during period considered. Figures for rails based largely on estimates of number caught in muskrat traps and used for food by trappers, with estimated value of $1.00 each. About 1/3 of annual fur crop produced by fresh marsh.

by fresh marsh.

Table 5. Wildlife and Fishery Values, Salt Marsh, Louisiana.

Unit	Total populations and values			Average annual crop values		
	Number (Pounds)	Unit value	Total value	Kill (pounds)	Unit value	Total value
Ducks	4,000,000	$5.00	$20,000,000	295,000	$5.00	$ 1,475,000
Fur	est. 2/3 of State		15,000,000	est. 2/3 of State		5,240,000
Rails	2,000,000	1.00	2,000,000	300,000	1.00	300,000
Sport fish	est.		20,000,000	est.		10,000,000
Comm. fish	est.		15,000,000	est.		5,000,000
Shrimp	est.		75,000,000	est. 1944 data		48,669.840
Oysters	est.		30,000,000	est. 1939 data		14,919,066
Total			$37,000,000 * (excluding salt water fisheries)			$85,603,906 (including salt water fisheries)
Value per acre			$14.80			$34.24

Note:--This sum includes only the first three units. Production of shrimp, oysters, and salt water fish of coastal bays is intimately related to production of food organisms in adjacent salt and brackish marshes. These items are therefore included in crop values for salt marsh, partly because they are produced by that marsh, and partly because their full utilization is interfered with by weed blockage of channels that are means of access to fishing waters. Sport fishing in this case includes pole fishing, shrimping and oystering done by private individuals for sport and food but not for sale. Salt water fisheries are not included in computation of land values. A considerable acreage of water bottoms in the coastal marshes have already been ruined, at least temporarily, by alligatorweed. These bottoms would otherwise have been suitable for oyster culture and sport fishing. However, all of the coastal bays and bayous contribute to these fisheries. Therefore land values of salt marsh are based on fur and waterfowl production only. Rails are caught in muskrat traps by trappers and used as food.

Table 6. Investments in trapping industry (individual trapper).

Initial investments

Camp	$ 300.00
Boat	300.00
Pirogue	50.00
Traps (300)	200.00
Stretchers, etc.	150.00
Total	$1,000.00

Average useful life, 10 years = $100 per annum.

Annual

Gas, lube, food	$125.00	
Boots, clothing, misc. equip. and repairs	75.00	
Total	$300.00	per annum

Table 7. Investments in private and public hunting and fishing Clubs.

Large commercial or private clubs.

Invested in plant and lands.

Clubhouse	$ 5,000.00	
Boats and pirogues	2,500.00	
Outbuildings, decoys and misc.	2,500.00	
Total	$10,000.00	(average life 10 yrs.) = $1000.00 per annum.)

Annual operating costs.

Salaries (superv. and labor)	$2,500.00	
Land maintenance (blinds, trails, plantings)	500.00	
Plant maintenance, repairs and upkeep	200.00	
Operating (gas, etc.)	300.00	
Lease or taxes	500.00	
Annual total per club	$5,000.00	
40 clubs in State		$200,000.00

Table 7. - Continued.

Smaller private and commercial hunting and fishing camps and boat landings.

Plant and lands

Camp or bunkhouse	$ 700.00		
Boats (average 5)	300.00		
Cabins (average 3)	1,000.00		
Total	$2,000.00		
Average life, 10 years =		$200 per annum	
Annual maintenance and operation		$300.00	
Lease		100.00	
Annual total per club		$600.00	
500 in State			$300,000.00
Grand total per annum.			$500,000.00

Table 8. Investments in commercial fisheries (mainly freshwater) Louisiana.

Units	Number	Unit Value	Total value	Life	Annual Value
Boats					
Motor	2,000	$ 1,000	$2,000,000	10 yr.	$ 200,000
Other	3,000	100	300,000	5 "	60,000
Apparatus					
Haul seines	500	400	200,000	1 "	200,000
Gill nets	100	75	7,500	1 "	7,500
Trammel nets	100	150	15,000	1 "	15,000
Lines (trot, set,)	20,000	8	160,000	1 "	160,000
Hooks	3,000,000	1/100	30,000	.5 "	60,000
Fyke nets	10,000	30	300,000	1 "	300,000
Misc. and licenses			454,303	1 "	454,303
Shore Plants	100	20,000	2,000,000	20 "	100,000
Total			$5,466,803		$1,556,803/annum

Note:—Data based on Survey, Fisheries Industries of U. S., 1932, U. S. Bureau Fisheries but values and numbers adjusted for prevailing costs and increases in plants.

SUMMARY AND RECOMMENDATIONS

1. This report concerns the relation of certain aquatic weeds to the wildlife and fisheries of the Gulf Coast. The investigations reveal that water hyacinth and alligatorweed are particularly detrimental to wildlife, and are responsible for the greater part of the damages reported.

2. The water hyacinth blankets freshwater ponds and streams, destroying the fish therein, and ruins the waterfowl habitat. Alligatorweed is an even more serious threat to wildlife and fisheries, since it thrives on dry land and in fresh and brackish marshes. Alligatorweed has already destroyed a vast acreage of valuable waterfowl and muskrat marshes, and is now threatening the salt-water fisheries of inner coastal waters.

3. These weeds seriously interfere with utilization of resources that furnish recreation, food, and a means of livelihood for an estimated 150,000 waterfowl hunters, 20,000 trappers, 150,000 sport fishermen, 225,000 cane pole fishermen, and 7,500 commercial fishermen in the Southern States.

4. The wildlife crop these weeds destroy each year in Louisiana is valued at $14,727,000. The annual crop loss in Florida amounts to $5,316,500.

5. Capitalized at a rate of 4 percent, the fish and wildlife resource which is affected annually in Louisiana is worth $368,000,000; in Florida it is worth $133,000,000. This amount is growing each year as the weeds invade new areas.

6. Unless hyacinth and alligatorweed are brought under control in the very near future, the wildlife and fisheries resources of the wet-lands of the entire Gulf Coast will be damaged further, and in some cases utterly destroyed.

7. Since these resources are of great importance to the States of the Gulf Coast and the South Atlantic seaboard, and since tourist fisheries and migratory waterfowl are a portion of a resource that has a national and international significance, immediate control of destructive water weeds is warranted.

8. The field investigations and experiments conducted by the Fish and Wildlife Service show that the weed control methods currently employed or contemplated, are not seriously detrimental to wildlife and fisheries. The temporary damage resulting from the decomposition of the killed plants will cause extremely small losses compared with those brought about by the weed infestation itself. Suggestions are offered, herein, for fish rehabilitation following weed-control operations.

9. In view of the above, the Fish and Wildlife Service recommends:

(a) That immediate and complete control of water hyacinth and alligatorweed be undertaken, if the aquatic wildlife and fisheries of the States of the Gulf Coast and the South Atlantic Seaboard are to be maintained and utilized as a natural resource;

(b) That Federal, State and private agencies utilize every known efficient means to accomplish this end;

(c) That such control may be undertaken in the light of present data without fear of causing to wildlife and fisheries damages that will be any more serious than those already brought about by weed infestation;

(d) That such control be undertaken as soon as practicable, since the undersirable after-effects of weed control are aggravated by prolonged infestation;

(e) That agencies undertaking control maintain liaison with the Fish and Wildlife Service, in order to prevent use of new chemicals that may be injurious to wildlife and fish.

APPENDIX A.

INVESTIGATIONS OF THE EFFECT OF THE WATER HYACINTH ON THE FISH AND FISH HABITATS OF LOUISIANA WATERS

By

Joseph E. King and Arthur L. Smith, Jr.

TABLE OF CONTENTS

INTRODUCTION

Beginning about the middle of July equipment was assembled and work started on the problem of determining (1) the effects of the water hyacinth on fish and fish habitats, (2) the effects of hyacinth control methods on fish, and (3) for comparison, to determine also the effects of some of the other aquatic weeds prevalent in the area.

It was our opinion that the direct effects of the hyacinth upon water chemistry were chiefly limited to its influence upon (1) dissolved oxygen, (2) free carbon dioxide, and (3) acidity (pH). Therefore, preparations were made for field analyses of these three factors only.

It was our belief also that the hyacinth so changed its aquatic environment as to make it unsuited for plankton and bottom dwelling organisms, forms of life being of great importance in the food chain of fish. It was our intention to obtain as much information as possible on this phase of the problem.

As the work progressed we hoped to utilize the hyacinth control operations of agencies engaged in the development and testing of new chemical herbicides for our purposes of determining the effects of these chemicals on fish life.

At every opportunity information was secured from game and commercial fishermen, fishing clubs and organizations, and officials of the State Department of Wildlife and Fisheries as to their viewpoints and evaluations of damage done by the water hyacinth to fishery resources.

All the work was performed in Louisiana with the exception of one short trip into Florida to investigate certain particular conditions there and to correlate our methods and data with those of Mr. T. K. Chamberlain, who was carrying out a similar assignment in that region.

GENERAL METHODS

Dissolved oxygen was determined by the Winkler method.

Free carbondioxide was determined by the Seyler method.

The results of these determinations are expressed in parts per million (ppm).

The water samples for these tests were taken at about one foot below the surface.

All temperatures are expressed as degrees Fahrenheit.

Water temperatures were taken at the surface.

The fish used for the survival experiments were, with one exception which is indicated, hatchery-reared, fingerling, largemouth bass of about 3-3.5 inches total length.

The live boxes used had dimensions of 24" x 18" x 15" and were covered with 1/4" mesh galvanized wire.

The bottom samples were taken with a 6" x 6" Ekman Dredge.

The plankton samples were taken by pouring a measured amount of water through a standard type silk straining net.

RESULTS

A. Effects of the Water Hyacinth on various types of water in Louisiana.

1. Lakes

Old River (Jaffer's Lake)
Natchitoches Parish, La.

History:

Jaffer's Lake was formed some time prior to 1928 by the construction of an earthen dam across Old River. The lake was about 9 miles long but very narrow, as it was largely confined to the Old River channel. It was stocked with crappie, bream and largemouth bass obtained from a hatchery in Arkansas. The lake became noted for its excellent fishing.

Water hyacinths came in 1933. By 1943, the lake was completely covered. In 1943 the dam was dynamited and the lake drained. Screens were placed across the outlet to prevent the exit of fish. The remaining pools were thoroughly seined with commercial gear. The catch was 3,700 pounds of coarse fish, mostly buffalo, and one large catfish (42 pounds). No game fish were present.

The above information was secured from Mr. S. H. Johnson, Natchitoches, Louisiana.

The dam was never restored, and in its present condition the stream is shallow with little or no current and almost completely covered with hyacinths. It is of little or no value for fishing.

Station 1. Open pool near turn-around, Culpepper Place, August 5, 1946.
Water temperature = 85° Air temperature = 94°
pH = approximately 8.1
DO = 6.4 ppm
CO_2 = 27.0 ppm
At margin of hyacinths and open water, DO = 2.66 ppm
Under hyacinths, 3 feet from open water, DO = 2.32 ppm
Under hyacinths, 5 feet from open water, DO = 0.70 ppm
Under hyacinths, 15 feet from open water, DO = 0.86 ppm
20 fish placed in live box in open pool survived for 3 days with no mortality.

Station 2. Under dense hyacinth mat, August 5, 1946.
Water temperature = 88° Air temperature = 93°
pH = approximately 6.8
DO = 0.38 ppm
CO_2 = 39.5 ppm
20 fish in live box at this station survived 3 days with no mortality.

Station 3. Under dense hyacinth mat, August 5, 1946.
Water temperature = 85° Air temperature = 93°
ph = approximately 6.8
DO = 1.0 ppm
CO_2 = 31.0 ppm
20 fish in live box at this station survived 3 days with no mortality.

Station 4. Open pool at Culpepper Bridge, August 5, 1946.
Water temperature = 92° Air temperature = 90°
ph = approximately 8
DO = 6.66 ppm
CO_2 = 25.3 ppm
20 fish in live box at this station survived 3 days with no mortality. Shad of about 1 foot in length were observed in the pool.

Station 5. Under dense hyacinth mat at Culpepper Bridge, August 7, 1946.
Water temperature = 92° Air temperature = 95°
ph = approximately 6.6
DO = 0.20 ppm
CO_2 = 63.5 ppm
All 20 fish were dead in live box at this station after 24 hours.

Northwest Game and Fish Preserve
Natchitoches and Winn Parishes, La.

By the construction of Alan Dam on Big Saline Bayou in 1937, several lakes were formed having a combined area of 94,000 acres. Black, Clear and "The Prairie" Lakes were formed on Black Bayou; Saline Lake and Chee-Chee Bay on Little Saline Bayou.

The impounded areas are still rather heavily covered with small cypress and gum trees many of which are dying or dead. There is much brush and stumps resulting from fallen and cut over timber. In some regions the "button-ball bush" has taken over making the water almost impassable by boat. The lakes are similar in most respects except that at present there are more open areas in Black and Clear Lakes than in Saline Lake. Also there are no hyacinths in the Black Bayou Lakes except for a small plot of 8 to 10 acres in Clear Lake near Smith's Camp. These were sprayed in the summer of 1946 and supposedly killed.

The lakes on Little Saline Bayou are badly infested. Saline Lake, of about 30,000 acres, is estimated to contain from 5,000 to 10,000 acres of hyacinths. From 75 percent to 80 percent of the fishing waters have been covered.

Work in this region was started early in August when the lakes were at a very low level as a result of a drawdown for the purpose of repairing the dam. Although conditions were definitely worse in hyacinth infested areas, the lakes in general were very stagnant and not very desirable for fish life. Although fish were present in abundance, the fishing was reported poor as the fish were not striking. Late in August the dam was closed and by our second visit in October there had been sufficient rains to greatly improve conditions as indicated by the water analyses.

Saline Lake

Station 6. Open channel below entrance to Brad's Camp. Channel about 40 feet in width bordered by dense hyacinths. About one mile above this point the channel is completely blocked for at least two miles. So the water tested here had flowed under at least two miles of hyacinths.

	August 9	October 22
Water temperature	85.5°	71°
Air temperature	85°	82°
pH approximately	6.6	6.2
Depth	11 ft., current strong	11-1/2 ft., current slight
DO	0.22 ppm	3.30 ppm
CO_2	20.2 ppm	29.8 ppm

20 fish when placed in a live box at this station, August 10, were all dead within 24 hours. Fish showed distress when placed in the water.

Station 7. Below entrance to Brad's Camp at margin of open channel and hyacinths, August 9, 1946.

Water temperature = 85.5° Air temperature = 85°

Depth 6-1/2 ft., current moderate

DO = 0.16 ppm

CO_2 = 22.0 ppm

20 fish in live box at this station August 10 all died within 24 hours. Fish showed distress when placed in the water.

Station 8. Below entrance to Brad's Camp under dense hyacinth mat 5 feet from open channel, August 9, 1946.

Water temperature = 85° Air temperature = 85°

Depth 5-1/2 ft., no noticeable current

DO = none

CO = 32.7 ppm

Station 9. Below entrance to Brad's Camp under dense hyacinth mat 15 feet from open channel.

	August 9	October 22
	Hyacinths green and living	Hyacinths dying and decomposing following spraying one month previous.
Water temperature	85.5°	72°
Air temperature	85°	82.5°
pH approximately	6.4	6.0
Depth	4-1/2 ft., no current	4-1/2 ft., no current
DO	None	3.42 ppm
CO_2	18.0 ppm	25.0 ppm

20 fish in live box at this station August 10 all died within 24 hours. Fish showed distress when placed in the water. The dissolved oxygen in a small creek flowing into the lake near this area was 4.86 ppm.

Station 10. Near Mulligan Inn Camp, in open channel about 1/2 mile above the dense hyacinth infestation.

	August 9	October 22
Water temperature	89.5°	75°
Air temperature	92°	85°
pH approximately	6.8	6.2
Depth	10 ft., current slight	10 ft., no current
DO	3.64 ppm	5.6 ppm
CO_2	11.5 ppm	22.6 ppm

About 2 weeks after the tests were made on August 9, 40 fish in 2 live boxes died within 24 hours at this station. We believe the DO was reduced considerably by falling water levels during the 2 weeks. Plankton and bottom samples were taken at this station, August 20, 1946.

Station 11. Near Mulligan Inn Camp, on flat area off main channel 75-100 yards, August 9, 1946.

Water temperature = 91° Air temperature = 92°
Depth 8 ft., no current
DO = 2.66 ppm
CO_2 = 14.5 ppm

Considerable fishing is still being done in Saline Lake in the open waters existing in the hyacinth covered area as well as that portion of the lake above the hyacinths. At Stations 6 and 7, largemouth bass, bream and crappie are common, where the dissolved oxygen is hardly more than a trace. Garfish, buffalo, gaspergoo, and shad are also present.

Black Bayou, below Clear Lake

Station 12. Black Bayou about 200 yards above its junction with Little Saline Bayou. No hyacinths at or above this point on either bayou or lakes.

	August 9	October 22
Water temperature	87.5°	76.5°
Air temperature	90.5°	83.0°
pH approximately	6.6	6.4
Depth	19 ft., current strong	19 ft., no current
DO	4.44 ppm	7.26 ppm
CO_2	8.4 ppm	12.9 ppm

20 fish in live boxes were all living at the end of 24 hours. Plankton and bottom samples were taken at this station, August 20, 1946.

Little Saline Bayou, below Saline Lake

Station 13. Little Saline Bayou about 200 yards above its junction with Black Bayou. Scattered clumps of plants were floating down the bayou but there are no dense growths of hyacinths between this point and Saline Lake, which is 3 to 4 miles above.

	August 9	October 22
Water temperature	88°	81.5°
Air temperature	91°	83°
pH approximately	6.2	6.3
Depth	17 ft., current moderate	17 ft., no current
DO	0.94 ppm	6.44 ppm
CO_2	19.7 ppm	10.8 ppm

20 fish in live box all died within 24 hours. Showed immediate distress when placed in the water. Plankton and bottom samples were taken at this station, August 20, 1946.

Black Lake

Station 14. Black Lake above highway crossing, August 21, 1946.
Sample 1. Large open area about 1/2 mile above highway bridge.
Water temperature = 85.5° Air temperature = 82.5°
Depth 7 ft., no current
DO = 4.16 ppm
CO_2 = 9.3 ppm
Plankton and bottom samples were taken at this locality.
Sample 2. Taken under red algal scum.
DO = 4.12 ppm
CO_2 = 10.2 ppm

Lake Fletcher
Lafayette Parish, La.

History:

The following information was supplied by Dr. Fred W. zurBurg of SLI:

"Lake Fletcher is a made lake, having been built by W.P.A. labor about 10 years ago. At that time, the lake was stocked with fish. About two or three years later, two bushels of water hyacinths were introduced into the lake to improve the natural beauty of the site. Within two years, the fish had apparently disappeared and the hyacinths had taken over the scene.

"In 1943 a sincere attempt was made to rid this lake of hyacinths by removing the plants by hand. This attempt was abortive. In the year 1944, an attempt was made to destroy the hyacinths by spraying with fuel oil. In this case, the leaves of the plants were burned out but no permanent remedy resulted as the plants re-sprouted. In the spring of 1945, the first attempt was made to remove the hyacinths by herbicides.

"In March 1945, experiments were started on the utilization of the phenoxy compounds. Small plots were sprayed at each trial. A number of the phenoxy compounds were synthesized; but, in general, the rate of application was about one pound of phenoxy compound per acre of plants (this calculated on the basis of the active, 2,4-D acid).

"By August 1945, the entire lake surface was covered with a mat of dead, brown hyacinths and no live plants were apparent. This mat was very dense and continued to remain on the surface until January. At this time the mat started to break and settle in part. This sinking of the mat continued and was not completed until about the first of May. During this process, it was noted that hyacinth seedlings grew on the decomposing mat and on the lake shore, but apparently there was no germination in the clear water.

"From May 1946, to date, the mat has remained on the bottom of the lake and is now (August 1946) in a state of decomposition. The seedlings which had germinated on the mat during the spring, were periodically sprayed (spot sprayed) with 2,4-D compounds. No hyacinths were allowed to form seed during the 1946 season.

"Surface minnows were observed in the water as soon as the mat started to break. Mr. Nelson observed a large perch in the lake in June 1946."

The lake is small, of about 2-3 acres, with a maximum depth of 6-8 feet. At present there are no hyacinths except for a few young plants resulting from seed germination. The bottom is now covered to a depth of 1-1-1/2 ft. with a slushy detritus resulting from the decaying hyacinths. Masses of this material sometimes rise to the surface, probably buoyed up by accumulating gas. Gas bubbles were seen continually breaking on the surface. In two dips of the seine, which were made with great difficulty, we took a young bream, many top minnows, and a small bullhead catfish.

Station 15. Lake Fletcher.

	August 22	August 23
Water temperature	90.5°	87.5°
Air temperature	86.5°	86.4°
DO	9.00 ppm	8.52 ppm
CO_2	4.7 ppm	5.6 ppm

40 fish in two live boxes were all living after 24 hours.

Small Fishing Lakes in New Orleans District

Waggaman Pond

Waggaman Pond is a portion of the Willswood Plantation which was a drainage project abandoned in 1928. It is within short driving distance of New Orleans and for many years has provided excellent fishing and waterfowl hunting. The lake has now 60-75 percent of its surface covered with water hyacinths and a good part of the time the only route of access to the open water is blocked by these plants. Visited August 30, 1946.

Station 17. Open water 50 yards from shore. Very little underwater vegetation present.

Water temperature = 82° Air temperature = 81°

DO = 3.68 ppm

CO_2 = 6.9 ppm

Plankton and bottom samples were taken at this station.

Station 18. At margin of hyacinths and open water.

Water temperature = 81.5° Air temperature = 82°

DO = 0.68 ppm

CO_2 = 20.0 ppm

Collections were made from root systems of three plants at margin.

Station 19. Under dense hyacinth mat, 5 ft. from open water. Some alligatorweed present.

Water temperature = 81° Air temperature = 83°

DO = None

CO_2 = 48.3 ppm

Station 20.

Sample 1. Under dense hyacinth mat, 15 ft. from margin.

Water temperature = 84.5° Air temperature = 85°

DO = 1.90 ppm

CO_2 = 16.4 ppm

Sample 2. Under dense hyacinth mat, 75 ft. from margin.

Water temperature = 84° Air tempperature = 85°

DO = None

CO_2= 63.7 ppm

Collections were made from root system of three plants. Bottom samples were taken.

Additional Analyses:

1. In open water, no hyacinths but containing both living and dead *Najas*.
   DO = 10.34 ppm
   CO_2 = No free CO_2, pH above 8.4
2. In open water, *Najas* mostly dead and disintegrating. Much algae on the surface.
   DO = 10.30 ppm
   CO_2 = No free CO_2, pH above 8.4

Roy Bougeres' Ponds, off Rt. 90, near Bonnet Carre Spillway

These two ponds of 10 to 12 acres each were created in 1932 or 1933 when earth was removed for use in constructing levees for the Spillway. Hyacinths first appeared in 1939 or 1940. They were allowed to multiply in the South pond, which at present is completely covered with a dense mature mat. There has been no fishing in this pond since 1943. The North pond has no hyacinths and fair fishing. Visited September 3, 1946.

Station 21. North pond, no hyacinths.

Sample 1.

Water temperature = 84.5° Air temperature = 84.5°

DO = 7.86 ppm

CO_2 = No free CO_2, pH above 8.4

Sample 2.

DO = 7.74 ppm

CO_2 = None

Station 22. South pond, covered with mature hyacinth mat.

Sample 1.

Water temperature = 71.5° Air temperature = 84.5°

DO = None

CO_2 = 36.3 ppm

Sample 2.

DO = None

CO_2 = 37.1 ppm

Collections were made from root system of three plants.

Churchhill Farm

Churchhill Farm was a drainage project of approximately 800 acres, which was abandoned as such and subsequently became an excellent lake for fishing and waterfowl hunting. At the present time there are considerably less than 100 acres of open water. The balance is infested with water hyacinths, alligatorweed and lotus. Visited, September 13, 1946.

Station 27. Churchhill Farm Lake.

Sample 1. Under mature hyacinth mat, 12 ft. from margin.

Water temperature = 82° Air temperature = 85°

DO = None

CO_2 = 13.3 ppm

pH = 6.8

Collections made from root systems of three plants at margin and 15 ft. under mat.

Sample 2. In open lake, no hyacinths. Very little underwater vegetation at this location.

Water temperature = 82.5° Air temperature = 85°

DO = 6.82 ppm

CO_2 = 2.5 ppm

pH = 6.9

Plankton sample taken.

Sample 3. Under young lotus plants with most leaves floating on surface. Considerable Ceratophyllum present.

Water temperature = 82.5° Air temperature = 85°

DO = 3.48 ppm

CO_2 = 5.8 ppm

pH = between 6.9 and 8.0

Station 27 - Continued.

Sample 4. Under old lotus plants; many leaves dead; most living leaves raised above water surface; much algae on the water surface. Considerable *Ceratophyllum* present.

Water temperature = 84° Air temperature = 85°

DO = None

CO_2 = 17.6 ppm

pH = 6.9

Either bream or crappie were continually breaking water in the areas of samples 3 and 4.

Largemouth bass, bream, crappie, and warmouth perch are common to abundant in the open areas of the lake.

2. Rivers

Rivers Draining into Lake Maurepas and Lake Pontchartrain

Rivers draining into these two lakes include the Amite, Tickfaw, Natalbany, Tangipahoa and Chefuncte, and their numerous tributaries. These are all clear-water streams noted for their excellent black-bass fishing. In the lower stretches of these rivers there are also, or have been, rather extensive commercial fishing operations.

The rivers vary greatly in their degree of hyacinth infestation. In practically all cases the plants are restricted to the lower stretches where the current is slight to moderate and many times is upstream instead of down as a result of tide and wind action.

In the Amite River the water hyacinth is only a marginal growth, very seldom reaching such a density as to cause jams or to interrupt navigation. Here the alligatorweed is more of a menace than the water hyacinth.

In the Tickfaw and its tributary the Blood, the infestation is very bad. At the time we inspected the area it appeared that 25 to 50 percent of the surface of this stream was covered with plants. Dense hyacinth jams frequently form which are a menace to flood control and make navigation impossible. Commercial fishing operations, particularly snag-line fishing for spoon-bill catfish, have been practically eliminated. It is impossible to maintain throw lines, trot lines, gill nets, or trammel nets where there are drifting rafts of hyacinths.

There are some hyacinths and alligatorweed as marginal growths in the lower regions of the other rivers mentioned, the Natalbany, Tangipahoa and Chefuncte, and in Bayou Lacombe, Bayou Liberty and Bayou Bonfouca, but nowhere were conditions observed to be quite as bad as in the Tickfaw and its tributaries. In all of the streams, 15 to 25 miles above their mouth, the hyacinth ceases to be a permanent resident and occurs only as a transient in the form of a few scattered plants drifting downstream with the current. Where the current is moderate to strong, the plants cannot maintain themselves in the body of the river and are found only in sheltered backwaters.

Station 25. Tickfaw River, Livingston Parish, September 10, 1946. About 1/2 mile above Easy Freeman's Camp near Rome's Ferry.

Sample 1. Taken at mouth of side stream which was completely choked with giant hyacinths. There was probably some mixing of the tributary with the open water, however.

Water temperature = 80° Air temperature = 80°
Depth 15 ft., current slight
DO = 3.06 ppm
CO_2 = 6.6 ppm

Sample 2. Open water, middle of Tickfaw River.
Water temperature = 81° Air temperature = 80°
Current moderate
DO = 5.2 ppm
CO_2 = 5.1 ppm

The main river at this point was at least 25 percent covered with rafts of hyacinths and, in addition, there was a dense margin of permanent growth.

Station 26. Blood River, tributary to the Tickfaw. Tangipahoa Parish, September 11, 1946. One-half mile above Kinchen's Camp.

Sample 1. Under hyacinth mat along margin. Mat about 40 ft. thick; sample taken 15 ft. from open water.

Water temperature = 82.5° Air temperature = 93.5°
Depth 13 ft., current slight
DO = 2.08 ppm
CO_2 = 7.3 ppm
pH = below 6.9

Sample 2. Open water, center of channel.
Water temperature = 83.5° Air temperature = 93.5°
Depth 19-1/2 ft., current moderate
DO = 4.34 ppm
CO_2 = 4.5 ppm
pH = below 6.9

Atchafalaya Floodway

The Atchafalaya Floodway, an area composed of the Atchafalaya River and adjoining bottom lands, is approximately 100 miles long by 10 to 20 miles wide. Bordering the river are vast areas of swamp land and numerous small lakes. The water hyacinth occurs here generally except under the more dense timber. Many of the small lakes are completely covered, others in varying percentages. Operations of the oil industry within the floodway are greatly impeded and rendered more costly because of the difficulty of maintaining open canals.

Fish kills occur quite regularly in the fall at time of low water. It seems probable that they are caused by an influx into the open waters of low oxygenated water from the swamps and hyacinth covered areas.

Station 30. Atchafalaya Floodway, September 26, 1946. In the Henderson area, near Breaux Bridge, St. Martin and St. Landry Parishes.

Sample 1. Open water in lake (Opelousas Bay) near Texas Oil Company Camp. Locality of annual fish kills. Has excellent sac-à-lait fishing in spring and summer.

Water temperature = 77.5° Air temperature = 79°
DO = 4.64 ppm
CO_2 = 31.3 ppm
pH = approximately 7.4

Sample 2. 30 ft. under hyacinth mat at upper end of Opelousas Bay.
Water temperature = 79° Air temperature = 79°
DO = 2.78 ppm
CO_2 = 53.0 ppm
pH = 7+

Sample 3. 50 ft. from edge of hyacinth mat in open water at upper end of Opelousas Bay.
Water temperature = 79° Air temperature = 77°
DO = 6.0 ppm
CO_2 = 30.8 ppm
pH = approximately 7.2

Sample 4. In swamp under mature mat.
Water temperature = 76° Air temperature = 77°
DO = 1.54 ppm
CO_2 = 73.0 ppm
pH = 6.2

Sample 5. In canal under mature mat.
Water temperature = 77° Air temperature 77°
DO = 2.16 ppm
CO_2 = 42.4 ppm
pH = 6.4

Sample 6. In shallow swamp, surface completely covered with old hyacinth mat.
Water temperature = 75.5° Air temperature = 77°
DO = 2.0 ppm
CO_2 = 80.9 ppm
pH = 6.6

3. Waters on Federal Refuges.

Station 28. Lacassine Refuge, September 24, 1946. On the Lacassine Refuge several other species of plants, such as *Brasenia*, *Utricularia* and *Cabomba*, as well as the water hyacinth, are presenting problems in water management. These plants tend to block the waterways thereby interfering with proper drainage and also making it difficult to patrol these waters by boat. It was thought of interest to determine what effect these plants might have on water as compared with that of the water hyacinth.

Station 28 - Continued

Sample 1. Above the Spillway under a dense growth of *Brasenia*; much *Utricularia* was present also.

Water temperature = 81.5° Air temperature = 84°
Depth 5 ft.
DO = 0.62 ppm
CO_2 = 26.8 ppm
pH = 5.6

Sample 2. Above the Spillway; no *Brasenia*; water filled with *Cabomba* and *Utricularia*.

Water temperature = 81.5° Air temperature = 85°
Depth 5 ft.
DO = 1.70 ppm
CO_2 = 23.4 ppm
pH = 5.8

Sample 3. Above Spillway in open water; no plants of significant amount.

Water temperature = 79° Air temperature 85.5°
Depth 9-1/2 ft.
DO = 1.18 ppm
CO_2 = 23.6 ppm
pH = 5.9

A 100 liter plankton sample was taken at this locality.

Sample 4. Near the Spillway but outside the impoundment in nearby marsh. Plants mostly *Sagittaria* and *Pontederia*.

Water temperature = 83.5° Air temperature = 85.5°
Depth about 1 ft.
DO = 0.66 ppm
CO_2 = 21.2 ppm
pH = 5.9

Station 29. "Big Burn" Marsh near the Sabine Refuge, September 25, 1946. Sample taken in pond almost completely covered with the white waterlily (*Castalia* sp.).

Water temperature = 79.5°
Depth 18 inches
DO = 1.4 ppm
CO_2 = 27.2 ppm
pH = 6.7

4. Bayous.

In southern Louisiana the bayou is a definite water type which is extensively used as a means of transportation and also for game fishing and other forms of recreation. The water hyacinth has found these slow-moving waters well adapted for its existence.

Conditions in Black Bayou and Little Saline Bayou, Natchitoches Parish, have already been described in the section dealing with the lakes of the Northwest Game and Fish Preserve.

Bayou Black, Terrebonne Parish
Along Rt. 90 west of Houma. October 17, 1946

Station 40. Under dense mat of hyacinths; channel 75 percent covered.

Water temperature = 73° Air temperature = 81.5°
DO = 0.8 ppm
CO_2 = 4.5 ppm
pH = 6.4

Station 41. In open water but with a few hyacinths along the margins. Fishing is now very poor in this portion of the bayou. There were reported to be some bream and crappie present but no bass.

Water temperature = 72° Air temperature = 82°
DO = 1.66 ppm
CO_2 = 33.2 ppm
pH = 6.4

Bayou Du Large, Terrebonne Parish, South of Houma, La.

Station 42. October 17, 1946.
Sample 1. Under dense hyacinth mat, channel completely covered.
Water temperature = 68° Air temperature = 83°
DO = 0.42 ppm
CO_2 = 81.1 ppm
pH = 6.6
Sample 2. In open water below Theriot Post Office. Some hyacinths along margins. Also some Cabomba present. Fishing reported fair in the vicinity.

Water temperature = 74° Air temperature = 83.5°
DO = 6.1 ppm
CO_2 = 14.2 ppm
pH = 6.8

5. Borrow Pits.

The "borrow pits" of southern Louisiana are excavations created to obtain filling for road foundations and levees. They function to a certain extent as drainage canals but at most times are without current. Where they are not infested with hyacinths they usually support a good population of bream and other sunfish. They are well adapted to the water hyacinths, however, and probably in Louisiana 95 percent of this type of water is infested with hyacinths and alligatorweed.

Station 23. Borrow pit along Rt. 61 and 65, about 8 miles northwest of New Orleans, September 3, 1946. The water contained a dense stand of alligatorweed. The available surface was 75 percent covered with Lemna and Spirodela.

Water temperature = 79.5° Air temperature = 86.5°
DO = Not measurable
CO_2 = 17.2 ppm
pH = approximately 6.9

Station 25. Borrow pit along highway near Manchac, La., September 6, 1946.

Sample 1. Under dense stand of alligatorweed.
Water temperature = 83.5° Air temperature = 86°
DO = 1.52 ppm
CO_2 = 5.3 ppm
pH = 6.9

Sample 2. Under dense coverage of hyacinths.
Water temperature = 82° Air temperature = 86°
DO = 0.81 ppm
CO_2 = 17.6 ppm
pH = approximately 6.9

Station 39. Borrow pit along Rt. 90 west of New Orleans.

Sample 1. Under complete surface coverage of *Azolla*, *Spirodela* and *Lemna*. Some *Ceratophyllum* present below surface.
Water temperature = 69° Air temperature = 79.5°
DO = Non-measurable
CO_2 = 32.8 ppm
pH = 6.8

Sample 2. Under dense hyacinth mat.
Water temperature = 68.5° Air temperature = 79°
DO = Non-measurable
CO_2 = 44.4 ppm
pH = 6.6

B. Special Studies on Ponds of the Bonnet Carre Spillway, near New Orleans, La.

Within the Bonnet Carre Spillway are a number of small ponds which were created when earth was removed for the building of adjoining levees. These have been stocked with fish by high waters and contain fair numbers of bass and sunfish.

Station 24. Bonnet Carre Spillway, Pond No. 1. About 3/5 acre in size, completely covered with mature hyacinth mat. Top minnows numerous. September 6, 1946.

Sample 1. Lower end of pond
Water temperature = 78° Air temperature = 89°
DO = Non-measurable
CO_2 = 31.4 ppm
pH = approximately 6.9

Sample 2. Upper end of pond.
Water temperature = 79° Air temperature = 89°
DO = Non-measurable
CO_2 = 31.8 ppm
pH = approximately 6.9

Station 24 - Continued.

Pond No. 2. About 4/5 acre in size, 60 percent covered with hyacinths. There being two open pools separated by hyacinths. Sunfish and bass were observed in these pools, September 6, 1946.

Sample 1. Lower end of pond under dense hyacinth mat, 50 ft. from open pool.

Water temperature = 84° Air temperature = 86°
DO = 1.66 ppm
CO_2 = 14.6 ppm
pH = approximately 6.9

Sample 2. In open pool (lower), 50 ft. from hyacinth margin.

Water temperature = 82° Air temperature = 86°
DO = 2.74 ppm
CO_2 = 12.5 ppm
pH = approximately 6.9

Sample 3. In open pool (upper), 50 ft. from hyacinth margin.

Water temperature = 83° Air temperature = 86.5°
DO = 3.06 ppm
CO_2 = 12.2 ppm
pH = approximately 6.9

Sample 4. Upper end of pond under hyacinth mat, 20 ft. from open pool.

Water temperature = 83° Air temperature = 86°
DO = 1.28 ppm
CO_2 = 13.3 ppm
pH = approximately 6.9

Plankton and bottom samples were taken from Pond No. 2 on September 9, 1946.

Pond No. 3. Open pond entirely free of hyacinths. About 2 acres in area. October 15, 1946.

Water temperature = 70° Air temperature = 74°
DO = 7.36 ppm
CO_2 = 14.2 ppm
pH = 7.2

These ponds represent on a miniature scale much of the fishing waters of southern Louisiana; Pond No. 1 being completely choked with water hyacinth, Pond No. 2 having dense hyacinth margins but central open pools. It was our plan to have these treated with one of the new 2,4-D preparations and determine: (1) if the chemical would kill the plants, (2) if the chemical would kill the fish which had been observed in Pond No. 2, (3) the time required for the dying plants to decompose and sink, (4) effects of their decomposition on the dissolved oxygen and carbondioxide content of the water, (5) the effects of the decomposition on fish, and (6) the time required for the ponds to return to what might be called a normal state.

On September 16, Pond No. 1 was sprayed by the U. S. Engineers with 275 gallons of 1,000 ppm Weedone. All plants were very well covered. The solution was applied in the form of a fine mist from a Bean high-pressure sprayer. On September 20, Pond No. 2 was sprayed in the same manner with about 250 gallons of 1,000 ppm Weedone.

At this date almost all the plants which were killed by the Weedone treatment are still floating. Those plants whose tops were killed but not the rhizomes have put out sufficient regrowth so that the ponds are beginning to look green again. In the pools of Pond No. 2 there have been observed bass, sunfish, top minnows, turtles and blue crabs, all of which are still quite active and apparently normal despite the unfavorable conditions of very low oxygen and high carbondioxide.

On these two ponds the one application of the herbicide did not produce the desired results of killing the plants and opening the water. There has been sufficient regrowth so that next spring, during the period of rapid propagation, the original concentration of plants will probably be restored.

We do not believe that in these two examples the decomposition of the sprayed plants has greatly changed the chemical content of the water so as to make it any less suitable to aquatic life than it was originally. The disoolved oxygen content and free carbondioxide have changed little since the spraying. Hydrogen sulphide has increased in amount but as yet has not reached a concentration toxic to fish. Observations of the ponds are to be continued to determine what the final effects of the treatment will be.

Table 1. - Pond No. 1.

No. of Weeks after treatment	DO (ppm)	CO_2 (ppm)	pH	Temp. (H_2O)	Condition of hyacinths
1	None	83.0	-	73	Browned but still standing. Coverage by treatment appeared 100 percent.
2	None	76.7	ap. 7	73.5	Plants appear to be dying but mostly still erect.
3	None	84.8	ap. 7	74.5	Same as above. Some putrefaction evident with odor of H_2S.
4	None	90.6	ap. 7	73	Same as above except some regrowth beginning to appear.
5	None	97.2	ap. 7	67.5	Considerable regrowth showing up.
7	None	104.8	ap. 7	71	Regrowth prominent, probably 10 percent. Dead plants rotting but still floating.

Table 2. - Pond No. 2

No. of Weeks after treatment	Open Pool				Under Hyacinth Mat				Condition of Hyacinths
	DO (ppm)	CO_2 (ppm)	pH	Temp. (H_2O)	DO (ppm)	CO_2 (ppm)	pH	Temp. (H_2O)	
1	1.60	34.4	7+	76.5	0.36	38.4	7+	76	Browned but still standing. Coverage with spray apparently complete.
2	3.12	32.5	7+	75.5	0.76	39.8	7+	77	Young plants around margin of pools appear to be decomposing rapidly. Dense mats still standing.
3	2.94	28.6	7	72	0.56	34.8	7	75	Young plants well rotted. Old plants mostly still standing.
4	1.54	40	7+	69	0.30	45.7	7+	70	Same as above. Evidence of regrowth appearing.
5	3.04	29	7+	69.5	None	39.8	7+	70	Considerable regrowth present.
7	1.63	28.4	ap.7	73	None	42.2	ap.7	72.5	Regrowth very evident, about 10 percent. Old plants rotting but still floating. One regrowth plant was flowering but flowers did not appear normal.

Fish Survival Tests - Spillway Ponds

On October 14, 1946, about 60 small fish of several species were seined from Pond No. 3 and placed in live boxes in Pond No. 2. The object was to determine if native fish from an adjoining pond could survive the unfavorable conditions prevailing under the decomposing hyacinth mat.

The results show that the fish could tolerate a reduction in their oxygen supply from 7.36 ppm to approximately 2 ppm, but could not survive at a DO of less than 1 ppm. The length of time that the fish did survive at this very low DO is truly remarkable.

Table 3. - Pond No. 2.

Live Box No. 1. - Placed in Open Pool

At Start	Contents	Size (Inches)	Temp. (H_2O)	DO (ppm)	CO_2 (ppm)
Oct. 14, 5 p.m.	2 *Dorosoma cepedianum*	5	75°	2.94	28.6
	1 *Pomoxis annularis*	5	"	"	"
	4 *Chaenobryttus gulosus*	3	"	"	"
	7 *Lepomis macrochirus*	2-1/2	"	"	"
	2 *Lepomis cyanellus*	3	"	"	"
	1 *Lepomis humilus*	3	"	"	"
Oct. 15, 8:30 a.m.	Mortality, 2 shad (*Dorosoma*); remaining fish in good condition.				
Oct. 16, 8:30 a.m.	All remaining fish in good condition.				
Oct. 17, 8:45 a.m.	All remaining fish in good condition.		69°	1.54	40
	The box and contents were moved to a position under the decaying hyacinth mat alongside box No. 2.				
Oct. 18, 8 a.m.	Mortality - 100 percent				

Table 3. - Pond No. 2 - Continued

Live Box No. 2 - Placed under decaying hyacinth mat.

At Start	Contents	Size (Inches)	Temp. (H_2O)	DO (ppm)	CO_2 (ppm)
Oct. 14, 5 p.m.	2 *Lepomis cyanellus*	3	75	0.56	34.8
	2 *Dorosoma cepedianum*	5	"	"	"
	2 *Pomoxis annularis*	5	"	"	"
	18 *Lepomis macrochirus*	2-1/2	"	"	"
	2 *Chaenobryttus gulosus*	3	"	"	"
	1 *Huro salmoides*	6	"	"	"
	1 *Eupomotis heros* (?)	2-1/2	"	"	"
	1 *Lepomis humilus*	3	"	"	"
Oct. 15, 8:30 a.m.	Mortality: 2 *Dorosoma cepedianum*, 2 *Pomoxis annularis*, 1 *Huro salmoides*, 12 *Lepomis macrochirus*, 1 *Lepomis cyanellus*				
Oct. 16, 8:30 a.m.	Additional mortality: 5 *Lepomis macrochirus*, 1 *Lepomis cyanellus*				
Oct. 17, 8:45 a.m.	Additional mortality: None		70°	0.30	45.7
Oct. 18, 8 a.m.	Additional mortality: 1 *Lepomis macrochirus*, 1 unidentified, possibly *Eupomotis heros*				
Oct. 19, 8:30 a.m.	Additional mortality: None. 3 fish remaining alive: 2 *Chaenobryttus gulosus*, 1 *Lepomis humilus*				
Oct. 25, 9 a.m.	Mortality - 100 percent. The remaining three fish were found dead. Exact time of death is not known.				

The shad (*Dorosoma cepedianum*) is a fish which is very sensitive to handling and its early mortality is probably attributable to this factor. The warmouth perch (*Chaenobryttus gulosus*) appeared to have a longer survival time than the largemouth bass and bream, although a definite statement to this effect could not be made on the results of these tests.

C. An Investigation of Certain Florida Waters.

A trip was made in company with Mr. John Lynch to investigate several Florida lakes which Mr. Chamberlain did not have the opportunity or time to visit; and also to compare and standardize methods and results of the water analysis work with Mr. Chamberlain and Mr. Erwin of the Belle Glade Laboratory.

Alligator Lake, Lake City, Fla.

Alligator Lake is a shallow lake of 300 to 400 acres in size, which was formerly about 2/3 covered with hyacinths. Sawboat operations under direction of the U. S. Engineers began shortly after September 1, 1946, and were discontinued in the first week of October. Approximately 1/2 of the hyacinths were cut up, most of which have sunk. Some decaying fragments have drifted and are deposited along the lake's margin to a width of 20-50 feet.

The lake went dry in the summer of 1943. It is subject to wide fluctuations of water level.

Station 31. Alligator Lake adjacent to Lake City Water Plant. October 7, 1946.

Sample 1. Under cut-up plants.
Water temperature = 73° Air temperature = 72°
DO = None
CO_2 = 33.8 ppm
pH = 6.0

Sample 2. In open water.
Water temperature = 73° Air temperature = 72°
DO = 4.7 ppm
CO_2 = 12.7 ppm
pH = 6.5

Sample 3. Under hyacinth mat, 15 ft. from margin.
Water temperature = 73.5° Air temperature = 73°
DO = 0.48 ppm
CO_2 = 24.3 ppm
pH = 6.3

Hamburger Lake, Lake City, Fla.

Hamburger Lake is a shallow lake of approximately 50 acres in size. The lake was formerly completely covered with hyacinths and no fishing was possible.

Sawboat operations during the month of August completely opened the lake. Only a few living plants remain along margin. Accumulations of decomposing plant fragments are 30 to 40 yards across along the west shore. The odor of H_2S was very evident.

The U. S. Public Health Service is spraying the lake at regular intervals with sodium arsenite for mosquito control.

Station 32. Hamburger Lake, October 7, 1946.
Sample 1. In open water.
Water temperature = 72° Air temperature = 73.5°
DO = 0.86 ppm
CO_2 = 29.3 ppm
pH = 6.3
Sample 2. Under decaying hyacinth plants.
DO = None
CO_2 = 30.7 ppm
pH = 6.3

Rose Lake, 6 Miles West of Orlando, Fla.

Rose Lake is a shallow lake of 200-300 acres in size, which was almost completely covered with hyacinths; only a few pools of open water remained.

Spraying operations started about July 1, 1946, small areas being treated at a time until the entire lake was covered. A commercial arsenite solution was used in spraying. The dead plants sank a week to ten days after spraying.

The entire lake is now open, only a few plants remaining along the margin. There has been good fishing since the open water appeared; one 8 lb. and one 14 lb. bass have been taken. Bream fishing is good.

It was reported that when the hyacinths encroached on the open water, the bass stopped biting and striking. The bream continued to bite, however, as long as any open water existed.

Station 33. Rose Lake, October 8, 1946.
Sample 1. In open water, 50 ft. from shoreline, considerable wave action.
Water temperature = 76° Air temperature 74.5°
DO = 6.06 ppm
CO_2 = 7.1 ppm
pH = 6.4
Sample 2. Under decayed plants at margin, marginal zone of decayed plants 20-30 ft. in width. (Impossible to take Sample 2 directly under mass of decaying plants because of great amount of detritus present.)
DO = 2.88 ppm
CO_2 = 13.1 ppm
pH = 6.0 ppm
Two dead Gambusia seen in decayed mat.

The three lakes described above demonstrate very well the results which may be expected from present hyacinth control methods. Alligator Lake never became completely covered with plants. The destruction of half of the plants present by means of the sawboat did not cause any significant changes in the oxygen or carbondioxide content of the open water.

Hamburger Lake was completely covered with hyacinths. Approximately 6 weeks after sawboat operations had ended there, the lake was still unsuited to fish life. Even though the lake was entirely open, the decomposition of plant fragments was holding the oxygen content down to a level not tolerated by most fish.

Rose Lake was never quite completely covered with hyacinths. The intermittent spraying operations did not result in any large mass of plants undergoing decay at one time. Therefore, the lake remained habitable for fish. At the end of the treatment the oxygen content was high and there were no large unsightly accumulations of decomposing plants. This method of removal seems well adapted to small scale spraying operations where plane application of the herbicide is not practical.

Hillsboro Drainage Canal
Opposite Univ. Experiment Station, Belle Glade, Fla.

This is a canal that was formerly covered with hyacinths, but repeated spraying with 2,4-D has reduced their numbers. There are still large mats of hyacinths in the canal, however.

Station 34. Hillsboro Drainage Canal, October 9, 1946.
Sample 1. Under dense hyacinth mat, surface completely covered.
Water temperature = 76.5° Air temperature = 82°
DO = None
CO_2 = 0.93 ppm
pH = approximately 7
Sample 2. In open water, 2-3 miles toward Belle Glade, Fla.
Water temperature = 76.5° Air temperature = 83°
DO = Non-measurable
CO_2 = 89.7 ppm
pH = approximately 7

The waters of this canal held a very high content of hydrogen sulfide. The Winkler method for determining dissolved oxygen is not considered reliable where large concentrations of this substance are present. Therefore, our DO readings for these samples, probably do not represent actual conditions.

Rim Canal, Lake Okeechobee, Fla.

This is a large canal that runs into Lake Okeechobee, Fla. It is used for navigation and contains large rafts of hyacinths. Fishing for catfish is supposed to be good.

Station 35. Rim Canal, October 9, 1946.
Sample 1. In open water near floating hyacinth island.
Water temperature = 77.5° Air temperature = 80°
DO = 7.12 ppm
CO_2 = 17.7 ppm
pH = 7+

Lake Trafford, Fla. (Lee County)

This is a large lake of perhaps 500 acres in size which, although largely open, is infested with a dense mat of hyacinths approximately 100 yards in depth along the east shore. One large bay is completely choked. Large rafts of the plants frequently move across the lake.

In the past it is reported that the lake enjoyed one of the best reputations in Florida for producing large numbers of big bass. At the present, fishing is poor and it is thought that the lake is "out of balance" in ratios of bream to bass. The bream apparently are able to spawn in great number, while bass spawning is greatly interfered with by the hyacinth mats that "sweep" across the spawning grounds.

Station 36. Lake Trafford, Florida, October 10, 1946.
Sample 1. In open water, 100 yards from shore.
Water temperature = 80° Air temperature = 82°
DO = 8.42 ppm
CO_2 = 4.3 ppm
pH = approximately 7+
Sample 2. Along margin of a rather temporary mat.
Water temperature = 80° Air temperature = 81°
DO = 7.86 ppm
CO_2 = 6.7 ppm
pH = approximately 7+
Sample 3. Under permanent mat of hyacinths, 75 yards from open water.
Water temperature = 78° Air temperature = 81°
DO = 1.62 ppm
CO_2 = 27 ppm
pH = 6.4 ppm
Station 37. In canal one mile north of Lake Trafford, Florida, October 10, 1946.
Sample 1. Under complete coverage of water lettuce (Pistia).
Water temperature = 85.5° Air temperature = 86°
DO = None
CO_2 = 43 ppm
pH = 6.4 ppm

Station 35 - Continued

Sample 2. In open pond, bottom covered with Chara; Bacona mineria also abundant.

Water temperature = 86° Air temperature = 86°

DO = 10.52 ppm

CO_2 = 11.5 ppm

pH = 6.6

Fisheating Creek, Lakeport, Fla.

This is a stream of rather slow current that is famous for its bass fishing. Fishing has been impeded for the last several years by dense growths of hyacinths along the margins, and rafts of hyacinths that float around in the stream.

One fisherman was observed casting from a highway bridge south of Lakeport while our analyses were being made; he hooked and landed three bass in a period of 20 minutes, the largest of about 2 lbs. in weight.

Station 38. "Fisheating Creek," 1/2 mile south of Lakeport, Florida.

Sample 1. In open water, current moderate.

Water temperature = 79° Air temperature = 83.5°

DO = 4.44 ppm

CO_2 = 12.9 ppm

pH = 5.8

Sample 2. Under dense hyacinth mat along margin, current slight.

Water temperature = 79° Air temperature = 83.5°

DO = 4.02 ppm

CO_2 = 19.7 ppm

pH = 6.0

Sample 3. Under dense hyacinth mat in tributary.

Water temperature = 79° Air temperature = 81.5°

DO = 2.4 ppm

CO_2 = 21.2 ppm

pH = 5.4

D. Bottom Fauna Studies.

It was our belief at the beginning of the investigation that a relationship would be found between the abundance and kinds of bottom dwelling organisms and the presence of the water hyacinth. We found, however, that the bottom fauna of the waters studied was very poor regardless of the presence or absence of the water hyacinth. The most widely distributed organisms proved to be Corethia and Chironomus larvae whose presence is indicative of low oxygen, high CO_2, and other conditions unfavorable to most insect and mollusc forms of life. The highly organic muck and ooze covering the bottoms of these waters is apparently not very productive. When no significant results were obtained after a number of samples had been taken in several water types, this phase of the study was discontinued.

Station 10. Saline Lake, channel near Mulligan Inn Camp, above concentration of hyacinths, August 20, 1946.

Depth 10 ft.

4 bottom samples, equalling 1 sq. ft. of surface yielded:

Insects: 1 dragonfly larva
4 *Corethra* larvae
1 *Chironomus* larva

Amphipoda: 1 *Hyalella*
1 *Gammarus*

Oligochaeta: 1 unidentified specimen

Station 12. Black Bayou, 200 yards above junction with Little Saline Bayou. No hyacinths above this point, August 20, 1946.

Depth 19 ft.

4 bottom samples, equalling 1 sq. ft. of surface yielded:

Insects: 2 dragonfly larvae
1 *Corethra* larva
5 *Chironomus* larvae
3 unidentified *Diptera* larvae
1 *Sialis* larva
1 *Hydrophilid* beetle

Molusca: 9 small unidentified clams of at least 3 species.

Station 13. Little Saline Bayou, about 200 yards above junction with Black Bayou; approximately 3 miles below Saline Lake and dense hyacinths, August 20, 1946.

Depth 17 ft.

4 bottom samples equalling 1 sq. ft. of surface yielded:

Insects: 2 *Corethra* larvae
5 *Chronomus* larvae
1 *Hapliplid* beetle

Mollusca: 2 unidentified small clams
2 " " snails

Oligochaeta: 8 unidentified specimens

Station 14. Black Lake, near central open area, August 21, 1946.

Depth 7 ft.

4 bottom samples equalling 1 sq. ft. of surface yielded:

Insects: 16 *Chironomus* larvae
1 *Chironomus* pupa

Station 17. Waggaman Pond; open water, 50 yards from shore, August 30, 1946.

Depth 2-1/2 ft.

4 bottom samples equalling 1 sq. ft. of surface yielded:

Insects: 5 *Corethra* larvae
2 *Chironomus* larvae

Mollusca: 2 unidentified snails

Station 20. Waggaman Pond, under hyacinth mat 50 ft. from margin, August 30, 1946.

Depth 2 ft.

2 bottom samples equalling 1/2 sq. ft. of surface yielded:

Insects: None

Amphipoda: 1 *Gammarus*

E. The Water Hyacinth as a Food Producer.

On several occasions we have heard the opinion expressed that the water hyacinth produced, or at least harbored, fish food and therefore was beneficial. This opinion was usually based on such observations as having seen schools of small fish nosing around the roots of the plant and the idea that generally, the best place in a lake to catch bass is along the margin of hyacinths and open water.

To obtain accurate information on this theory we examined the root systems of a number of plants. This was done by thoroughly washing the roots in a bucket of water and then straining the water through a fine sieve. The organisms thus collected were preserved for later identification and volumetric measurement.

The results indicate that whereas the root systems of plants along the margin of open water harbor an abundance of small organisms, those plants within the mat at some distance from open water are practically barren of life or at least have a relatively poor fauna. This variation is due, we believe, to the difference in oxygen content between the marginal water and that under the hyacinth mat.

Station 20. Waggaman Pond, August 30, 1946. Washings from the roots of 3 plants at margin of open water.

Volume = 1.95 cc. of organisms including:

damselfly larvae	*Gammarus*	*Planaria*
dragonfly larvae	*Hyalella*	Immature clams
Isopods (*Assellus*)	*Oligochaetes*	Snails

Washings from the roots of 3 plants, 75 ft. from margin of open water.

Volume = 0.4 cc. of organisms including:

1 Beetle pupa	19 Isopods (*Assellus*)	7 *Oligochaetes*
2 *Hapliplid* beetles	Numerous *Hyalella*	3 small immature clams
1 *Dytiscid* beetle	Numerous *Gammarus*	1 *Gambusia*

Station 22. Bougeres' Pond, September 13, 1946. Lake entirely choked with hyacinths. Washings from roots of 3 plants.

Volume = 0.2 cc. of organisms including:

1 *Hapliplid* beetle	2 *Oligochaetes*
Several misc. unidentified insect larvae	1 *Gambusia*
Numerous Isopods (*Assellus*).	1 Tadpole

Station 27. Churchhill Farm, September 13, 1946. Washings from the roots of 3 plants at margin of open water.

Volume = 1.0 cc. of organisms including:

Damselfly larvae	Hyalella	Snails
Dragonfly larvae	Isopods (Asellus)	Immature clams
Gammarus	Oligochaetes	

Washings from the roots of 3 plants 15 ft. from margin of open water.

Volume = 0.07 cc. of organisms including:

Hapliplid beetles	Gammarus	Snails
Spider	Isopods	
Hyalella	Oligochaetes	

F. Plankton Studies.

In southern waters, one of the main items in the diet of game fish is the shad (Dorosoma sp. and Signalosa sp.). The shad, in turn, is largely a plankton feeder. The young of most game fish also feed on plankton during certain phases of their development. This material is basic in the food chain of fishes and its relative abundance generally serves as an index to the productiveness of a body of water.

Studies were undertaken to determine what influences the water hyacinth might have on plankton life. We soon found that it was impossible to take a plankton sample under a hyacinth mat with the type of equipment we possessed. The straining net would immediately become clogged with the great amount of detritus resulting from the plants. Collections were made, however, from waters such as Little Saline Bayou, which had flowed under hyacinths for a considerable distance and had taken on the chemical properties of hyacinth-covered water.

Although there has been insufficient time as yet for specific identification and quantitative counts on the collections, a preliminary examination shows that the greatest abundance of plankton, consisting largely of Copepoda and Cladocera, was found in open lakes of high dissolved oxygen content. In none of our samples did we find Copepoda from waters of less than 1 ppm. DO. The richness of the collection varied generally with the quantity of oxygen present. On this basis we believe that the very low DO's prevailing under hyacinth plants together with the shading effect, would tend to discourage the growth of most forms of plankton life, such as Copepoda, Cladocera and phytoplankton. Further studies are necessary, however, before this can be definitely demonstrated.

G. Effects on Control Methods on Fish.

At present there are chiefly two methods employed for control of the water hyacinth. There are, first, the mechanical method which was developed by the U. S. Engineers and involves a floating machine which macerates the plants and either conveys the fragments to the shore or dumps them back in the water. The second, is the chemical method, the chemicals being one of the new formagenic herbicides, such as 2,4-D (2,4-Dichlorophenoxy Acetic acid) or its derivatives, which is applied in the form of liquid spray or dust from a boat, plane, or from the shore.

From our own short-time observations and those made over a period of years by the U. S. Engineers, it appears that the first method described has never resulted in the death of any significant number of fish. A few individuals may be cut up by the machine, but such losses are indeed minor. As the machines have been used largely in navigable waters where there is some current, there have been few instances of the accumulation and subsequent decomposition of plant fragments resulting in a critical change in the oxygen content of the water. We believe there is little possibility that this method of control may have any significant harmful effects on fish life.

The second method may influence aquatic life through a direct toxic action of the chemical itself, and also through the release of toxic products and other effects of plant decomposition.

The authors are aware of only three investigations which have been made to determine the direct toxicity of some of the new herbicides currently being recommended. The quotations given below are taken from as yet unpublished reports.

1. "Summarized Report on Toxicity of 2,4-D (2,4-Dichlorophenoxy Acetic Acid) For Certain Species of Fish," by M. M. Ellis, B. A. Westfall, and R. O. Jones, Water Quality Laboratories, U. S. Fish and Wildlife Service.

   "<u>General Summary</u>.

   1. In tapwater or hatchery water, 2,4-D in concentrations less than 100 ppm. produced little or no effect on salmon, goldfish, catfish and top minnows under conditions of the tests described herein.

   2. In concentrations greater than 100 ppm. and less than 400 ppm. there were from 10 to 15 percent losses in all series.

   3. Marked lethality appeared at 400 ppm. and high mortality in concentrations of 600 ppm. of 2,4-D.

   4. Reduction of dissolved oxygen in the water seemed to enhance the action of 2,4-D on the fishes studied."

2. "Preliminary Tests of Herbicides vs. Fishes" by Dr. Oliver B. Cope, U. S. Fish and Wildlife Service.

   "<u>Conclusions</u>.

   1. All the derivatives of 2,4-D used in these experiments are lethal to some fishes in concentrations of 1,000 ppm., and the process seems to be that of asphyxiation.

2. The two derivatives of dinitro-o-secondary butyl phenol used here are lethal to some fishes in concentrations of 100 ppm. and more. Death seems to result from causes other than asphyxiation.

3. Three-inch rainbow trout are more resistant to the action of 2,4-D than are six-inch rainbow trout, and two-inch brook trout are more resistant than rainbow trout tested.

4. Three-inch rainbow trout are more resistant to the action of dinitro-o-secondary butyl phenol than are six-inch rainbow trout, but two-inch brook trout are less resistant than both groups of rainbow trout.

5. Two-inch chubs, Siphiteles obesus, are slightly more resistant to the action of 2,4-D and dinitro-o-secondary butyl phenol than are any of the trouts tested.

6. The aquatic insects tested are more resistant to the actions of both chemicals than are the fishes.

7. Recovery of fish from sub-lethal doses is more successful after 2,4-D treatment than after dinitro-o-secondary butyl phenol."

3. "Effects of Two of the New Formagenic Herbicides on Bream and Largemouth Bass," by Joseph E. King, U. S. Fish and Wildlife Service and William T. Penfound, Tulane University.

Abstract of manuscript which has been accepted for publication in Ecology.

"Tests were made with two new formagenic herbicides, 2,4-D (2,4-Dichlorophenoxy acetic acid) and SLI-23 (a product of Southwestern Louisiana Institute), to determine their effect on fingerling bream (Lepomis macrochirus Rafinesque) and largemouth bass (Huro salmoides Lacepede). The fish were subjected to the following conditions: tapwater control, 1 ppm. of herbicide, 100 ppm. of herbicide, under hyacinth plants as a control, and under hyacinth plants sprayed with 1,000 ppm. of herbicide.

"Solutions of 1 ppm. of 2,4-D had no effect, whereas 100 ppm. produced a low but significant mortality. The SLI-23 at concentrations of 100 ppm. produced total mortality within a few hours; 1 ppm. had a very slight toxic effect.

"Fish under hyacinth plants sprayed with 1,000 ppm. 2,4-D or SLI-23 experienced no ill effects until the plants began to die and the subsequent oxidation lowered the dissolved oxygen content of the water beyond the toleration limits of the fish.

"The results indicate that, whereas the introduction of these chemicals into the immediate environment of the fish may have harmful effects, spray applications to surface vegetation at the rates recommended by the manufacturer will not be directly toxic to fish life. When the sprayed plants die, however, any fish trapped in the immediate vicinity and unable to escape to open water will probably die of asphyxiation."

These reports indicate that, in general, concentrations of less than 100 ppm. of the herbicide have no effect on fish. Concentrations above this amount are definitely toxic.

It has been found that the optimum dosage for killing the water hyacinth is a 1,000 ppm. solution applied at the rate of 200 to 300 gallons per acre. Even if 100 percent of the herbicide reached the water the resulting concentration would be less than 1 ppm. if the water exceeded a few inches in depth. There is little likelihood, therefore, that a concentration of 100 ppm. would ever be reached in a treated waterway.

There is the possibility, however, that when large masses of the sprayed plants decompose, the accompanying oxidation and release of CO_2 and H_2S may result in a fish kill. The tests, previously described, made on the Spillway ponds, have shown that in the sprayed pond in which there was some open water and fish, there has been a reduction in oxygen content and an increase in CO_2 and H_2S, but as yet no dead fish have been observed.

Much work remains to be done on this phase of the problem. It is desirable also that we know the effects of the herbicides on aquatic insects and plankton, both of which are very important in the food chain of fishes.

H. Evaluation of Damage to Freshwater Fisheries by the Water Hyacinth.

1. Commercial Freshwater Fisheries:

Sources of Information:

7th Biennial Report, La. Dept. of Conservation, 1924-1926.
Fisheries Industries of the U. S., 1932, U. S. Bureau of Fisheries.
(Latest Federal survey of freshwater fisheries.)

The values and numbers obtained from the above sources of information have been adjusted for prevailing costs and increases in the number of plants and are shown on page 27 of this report.

Production

1931 - 19,213,368 lbs. (Fisheries Industries of the U.S., 1932. Last Federal survey).

Or approximately	20,000,000	lbs.
	x .14	per lb. (River Basin Studies Value)
	$2,800,000	probable price to the fishermen
	2,800,000	profit by wholesalers and retailers
	$5,600,000	total annual income and commercial fisheries

Number of Individuals Receiving Income
and Louisiana Commercial Freshwater Fisheries

Figures for year 1931, last year of Federal survey. (Fisheries Industries of the U. S., 1932).

Fishermen on boats and shore:	Regular	1,402
	Casual	3,108
	Total	4,510

Probably 5,000 fishermen presently involved.

Total number of people supported by Louisiana freshwater fisheries in 1925 were 26,965. (7th Biennial Report, La. Dept. of Conservation, 1924-26).

2. Freshwater Game Fish Production and Value.

2,000,000	acres of freshwater (Until a better figure is proposed.)
x 10	lbs. per acre per year (Until a better figure is proposed.)
20,000,000	lbs. per year

Of which approximately	12,000,000	lbs. are pan fish
	0.75	per lb. (River Basin Studies)
	$9,000,000	annual crop value

And	8,000,000	lbs. are L. M. and Ky. Bass
	$2.00	per lb. (River Basin Studies)
	$16,000,000	annual crop value

Total value of annual crop:	$ 9,000,000	pan fish
	16,000,000	bass
	$25,000,000	

3. Combined Value of Commercial and Game Fisheries.

$25,000,000	game fish	
5,600,000	commercial	30,600,000 = $15.30 per acre per year
$30,600,000	Total	2,000,000 acres

4. Annual Fisheries Loss Resulting From Water Hyacinth and Alligatorweed.

500,000	acres infested in Louisiana (Estimation)
$15.30	fisheries crop value per acre per year
$7,650,000	Annual loss

CONCLUSIONS

A. Effects of the Water Hyacinth on Fish and Fish Habitats.

1. In all analyses of water under hyacinth plants we have found an oxygen content much less than what is considered necessary to support fish life.

   To supply its respiratory requirements the water hyacinth actually removes oxygen from the water. Other floating plants found to have a similar effect are *Lemna minor*, *Spirodela polyrhiza*, *Pistia stratiotes*, and *Azolla caroliniana*.

   The hyacinth also interferes with the normal interchange of gases between the water surface and the atmosphere, thus preventing the release of CO_2 and H_2S and the taking on of oxygen. The floating plants listed above have this same effect, as do also certain rooted plants, such as the water lilies (*Nymphaea* sp., *Nuphar* sp.), lotus (*Nelumbo lutea*), water-shield (*Brasenia schreberi*) and alligator grass (*Alternanthera philoxeroides*).

2. The water hyacinth produces an unfavorable environment for fish food. The low oxygen content prevailing under hyacinth plants together with the shading effect of the plants, produce conditions which are unsuitable for the existence of most forms of plankton and aquatic insect life.

3. The water hyacinth smothers out the spawning grounds of many game fishes. Dense marginal growths together with drifting rafts of the plants destroy the favorite spawning areas of the largemouth bass and probably other species as well.

4. In view of the above, we do not believe that game fish can persist for long in a body of water which becomes completely covered with hyacinths. Fish may survive while there are patches of open water, but not for long thereafter. In proof of this there are such examples as Old River (Jaffer's Lake) which had excellent fishing until the coming of the hyacinths. After the lake had been covered for some time, it was drained and nothing was found except coarse fish. Fishing has always dropped off in waters invaded by the hyacinth.

5. The encroachment of water hyacinths on open water upsets the predatory-prey relationship. Game fish are concentrated in small areas where they are easy prey to garfish and bowfin. These undesirable fish are the last to be eliminated in plant infested waters.

6. The presence of the water hyacinth speeds up lake succession. The great amount of detritus from these rank plants tends to build up the lake bottom until such rooted plants as cat-tail and willow may become established. As a result of this, many of our shallow lakes have in a period of a few years become senescent and are now beyond recovery.

7. Commercial fishing operations are greatly hindered and usually terminated when waterways become infested with the hyacinths. Seine, gill net, trammel net, hoop net, snag line, and trot line fishing become impossible.

B. Effects of Hyacinth Control Methods on Fish Life.

1. The chemical method is still in an experimental stage, but at this time it does not appear that the chemicals currently being proposed will have any direct effect on fish at the concentrations recommended for application. In certain types of water there may be an indirect effect resulting from the release of toxic decomposition products and the lowering of oxygen tensions.

2. The mechanical method of control has not resulted in loss of fish life in the types of water in which it has been applied. There is the possibility, however, that under certain conditions, the decay of plant fragments may have the same effect as the decomposition of sprayed plants.

3. It is our opinion that the primary problem is to eradicate the water hyacinth. Any fish mortalities resulting from control methods are of secondary importance. Fish life will be eliminated in time in any event in hyacinth infested waters. Where control methods have been employed, recovery of the waterway has been sufficiently rapid so that restocking could be undertaken, if needed, in the matter of a few months.

APPENDIX B.

INVESTIGATIONS OF THE EFFECT OF THE WATER HYACINTH ON THE FISH OF FLORIDA WATERS

By

T. K. Chamberlain

TABLE OF CONTENTS

INTRODUCTION

These studies were performed in association with Mr. Thomas C. Erwin, Assistant Chemist, of the Everglades Experiment Station of the University of Florida, Belle Glade, Florida. Material assistance was given the studies by the Vice-Director of that station, Dr. R. V. Allison, through the assigning of Mr. Erwin's time and through other means at his disposal.

Most of the work performed was carried out in the Everglades section of south Florida, in the general vicinity of Lake Okeechobee. While some study was made of Lake Trafford and of several rivers in south Florida, most of the work was performed on the various drainage canals of the Everglades Drainage District, that run from Lake Okeechobee to the Atlantic and to the Gulf Coasts. These canals for the most part had been constructed over 20 years, or before water hyacinth had appreciably entered this section of Florida.

OBJECT OF WORK

These studies were part of an overall appraisal of the water-hyacinth situation in the United States by the U. S. Army Engineers' Corps, with a view to a more complete control over the plant, if not its extermination. It had come to be seriously undesirable in Louisiana and Florida and was approaching this condition in several other states. With the development of the herbicide 2,4-D and the evidence of its effectiveness against water hyacinth, the question had arisen as to the possible harm that might be done to fish populations, if the water-hyacinth infested waters were treated in a wholesale way to remove the vegetation under consideration. As Mr. Lamar Johnson, Engineer in Charge of the drainage canals of the Everglades District, was beginning a program of 2,4-D treatment of the canal waters, which were almost 100 percent covered with the plant, these canals were given particular attention because this treatment was under way during the period of the Florida studies. The larger canals were sprayed with 2,4-D by plane. The smaller feeder canals were sprayed by hand from the bank.

The history of the Everglade canals, and to some extent that of other Everglades fresh waters, show that there have been severe mortalities among the fish populations from time to time. These had taken place before the water hyacinth had become prevalent, so it is apparent that when fish are found dying in the areaa the cause need not necessarily be attributed directly to the killing of water hyacinth with the herbicide. In case such a mortality developed while herbicide treatment was under way it became important to learn just what appeared to be the common cause of the death of Everglades fish. If the same conditions were found to exist as were known to be the usual cause of death, there would be no logical reason for blaming the herbicide.

APPROACH TO PROBLEM

When the work was started early in August it was planned to duplicate the chemical and other studies of the Louisiana unit. With this in mind a similar program of chemical analyses of water from water hyacinth habitat was begun, with emphasis on the dissolved oxygen present before, during and after the treatment of the water hyacinth with 2,4-D. A number of fish live-boxes were constructed to hold fish under the plants at various stages of treatment. It soon appeared desirable to concentrate for the most part on the particular Florida problem indicated in the preceding paragraph, namely the cause of death of numbers of fish in the Everglade waters at irregular intervals. The time available for the work was so limited that for the sake of efficiency it was thought best not to continue the taking of as frequent oxygen determinations as was done in Louisiana.

Before this decision to concentrate on the local Florida problem was made, some 60 individual dissolved oxygen determinations were taken. These merely helped to emphasize the fact already clear in Louisiana, that where a body of water is completely covered with water hyacinth, the amount of oxygen dissolved in the water is held close to, or below, that point considered the minimum amount satisfactory to the largemouth black bass and the desirable species of sunfish. Actual figures approached the zero mark. Since this, to start with, is about as unsatisfactory as possible, it is obvious that the situation could not be made worse from the standpoint of the fish population by the death and disintegration of the water hyacinth. Certain newspaper articles had suggested that the real harm to the fish population would be caused by the disintegration of the water hyacinths at one time, rather than by 2,4-D itself.

As the first series of dissolved oxygen determinations were being made it became apparent that more or less interference was being had from other substances in solution that were present in the Everglades muck soil. This required the working out of special techniques for water analysis by Mr. Erwin and various tests to determine just what the more important substances in solution actually were.

HYDROGEN SULFIDE

The search culminated in the discovery of the extent to which hydrogen sulfide occurred in the muck soil of the Everglades and the high concentration of the gas in Everglades waters after periods of rain. The steps leading to this discovery are inconsequential, but the discovery itself is considered of considerable importance. Florida Everglades muck soil averages over eight feet in thickness and consists of black organic material mostly of sour grass origin. It is composed of 0.33 percent by wet weight of sulfur. From this sulfur as source, hydrogen sulfide is formed in the soil under at least two conditions.

Anaerobic bacteria, working on the material is one. The second is considered more important of the two and is strictly mechanical. With the drainage of the Everglades the top of the soil becomes dry and because of its high organic composition has frequently caught fire. For the most part the combustion tends to be incomplete. That is, the amount of oxygen available for the combustion is limited and inadequate for complete combustion. When the sulfur burns, therefore, sulfides are formed for the most part rather than sulfates. When the alkaline sulfides are carried by rain into contact with the slightly acid soil of the wet unburned muck, hydrogen sulfide is given off, enters into solution, and is carried by the water that flows through the soil into the canals and to a considerable extent into Lake Okeechobee. Wave action during windy periods tends to eliminate the gas from the lake by an aerating action.

Hydrogen sulfide is quite toxic to fish. Six parts per million will kill carp in a few hours. In one subsidiary or feeder canal a concentration of over 40 parts per million was noted after a rain; it was sufficient to kill black bass, sunfish or catfish. Also hydrogen sulfide creates an oxygen demand. Where hydrogen sulfide is present to any appreciable extent there is insufficient dissolved oxygen present to sustain the fishes mentioned, granting the fish could tolerate the hydrogen sulfide concentration itself.

There have been many muck fires over different sections of the Everglades in past years. Tests of soil and water associated with these burned areas showed that hydrogen sulfide was likely to be present in considerable amounts if the fires had taken place within three to five years. The "spottiness" of the burned areas coincided with the "spottiness" of the areas or canals having high concentrations of the gas. This meant that while some small canals (as one running along the rear margin of the Station property) might at a given time show high concentrations of the gas in its water, other water areas not so far away might not show over two to four parts per million of the gas.

The canal bordering the rear of the station property showed on September 30, shortly after a heavy rain, 40 parts per million of hydrogen sulfide. On October 1, with no further rain, 18 parts per million were indicated. On October 2, also without rain, the amount was 15 parts. No test was made October 3, but on October 4 the gas had further dropped to two parts per million. There was a rain the night of October 7 and on October 8 the water registered 29.4 parts per million.

A test was made October 9 in the rim canal that encircles Okeechobee Lake. This water showed 7.2 parts per million of hydrogen sulfide to be present. It is more than probable that the reason the bulk of the fish population of Lake Okeechobee prefer to remain well away from the shore, and toward the center of the lake, is due to the hydrogen sulfide in solution, that the rains keep sufficiently concentrated along the shore line to drive the fish out into the lake. This in turn interferes with the reproductive and other activities of the fish and probably accounts for the production of both game and commercial fish in the lake being extremely low, as compared with such waters as the TVA reservoirs.

The presence of water hyacinth on waters having hydrogen sulfide slows up the process of aerating the undesirable gas out of the water and of building up the desired presence of dissolved oxygen in the water. Apparently hydrogen sulfide has no harmful effect upon the growth of water hyacinth itself.

Some of the lower fishes such as the gar, also turtles, salamanders, snakes and alligators, are able to live in water infested with water hyacinth and having considerable hydrogen sulfide in solution, through the ability of these animals to take in fresh air at the water surface or outside the water altogether. At no time were any of the animals named found dead unless they had been caught in traps under water and were unable to reach the fresh air.

While the animals referred to may be considered the only permanent residents of the canals at this time, bass, sunfish and catfish continually enter the canals during short periods of satisfactory water conditions. They enter from Lake Okeechobee and were found to reproduce when time permitted. Not only were adult fish found dead after unfavorable condions had set in, but young sunfish and catfish by the thousands were also found having survived for a period in isolated ditches associated with the canals, only to be killed when conditions became intolerable. Remains of innumerable young fish were found.

WATER HYACINTH IN LAKES

From a study of Lake Trafford in south Florida it was recognized that where a mat of water hyacinth has developed to a considerable extent, but lacks the growth sufficient to permit the "smothering out" effect apparent on small bodies of water, considerable damage may yet be done by what might be called a "Juggernaut action." That is, damage is done by direct physical action by the great floating mat of hyacinths. Spawning beds are scoured; desirable aquatic vegetation uprooted; spawning fish driven from their nests. Lake Trafford, through such action by the water hyacinth mat on that lake, had been ruined as bass water.

Thus while for the early stage of infestation of a body of water with water hyacinth, as happened in Lake Trafford, there may appear little harm and possibly limited benefits through the shelter it gives both fish and fish food, sooner or later the fish population is struck an irreparable blow when the infestation passes a given point.

The elimination of water hyacinth is a vital step in the preservation and recovery of good fishing in southern waters. Water hyacinth destroys fishing by reducing the oxygen content of water, by closing a body of water to the operation of boats and by the Juggernaut action of rafts of the plants. In the Everglades, however, there exists the added problem of building up fishing in spite of the presence of hydrogen sulfide. Through aeration devices this might be made possible.