METHODS OF MEASURING AND DETERMINING THE EFFECTS OF MARSH FIRES

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INTRODUCTION

According to St. Amant (1959) there are approximately 4,000,000 acres (12.9 per cent of the land area of the state) of marshland and waterways in South Louisiana, of which about 3,000,000 acres are true marshland. Many people derive a livelihood from this land by raising cattle, trapping, fishing, and leasing land for hunting purposes. This area serves as a wintering ground for thousands of waterfowl and many other migratory birds. The shallow bays and estuarine areas serve as a nursery site for many of the commercial marine animals. Although looked upon as wasteland by the uninformed, it is an extremely valuable region of the state.

The marsh has undoubtedly been burned since its origin, first by natural fires caused by lightning, and later by Indians as they occupied the higher sites. As the white man settled in and near the marsh, he stepped up the tempo of burning to make his trapping, waterfowl, and alligator hunting easier and to improve grazing for livestock. More observant people began to notice improvements in the condition of the marsh as a result of burning so that today all marsh management, whether for fur animal management, waterfowl management, or for cattle management, includes periodic or annual burning (O'Neil 1949). The major objectives of marsh burning are to give some of the more valuable food plants an advantage over those that are less desirable or to remove the dense rough and provide more succulent food for birds and mammals.

Despite the fact that burning is such a standard practice, little scientific study has been made of the effects of fires on the marsh. It is believed that the proposed study is the first attempt made to evaluate techniques of measuring factors associated with marsh fires.

Objectives of this study were to devise methods of measuring marsh fires and of evaluating them; to measure factors influencing marsh burns; and, to measure effects of marsh burns.

LOCATION AND DESCRIPTION OF STUDY AREA

LOCATION

This study was conducted on Rockefeller Wildlife Refuge, Grand Chenier, Cameron Parish, Louisiana. Precise location was in section 9, township 16 south, range 3 west. The burns were made along the Superior Oil Company canal in the vicinity of well number 26.

DESCRIPTION

Physiography. The study area, which was located in a low lying marsh with an elevation of one foot above Gulf level, was subjected to tidal action from the Gulf of Mexico. The area received very little fresh water runoff because of the interception of rainfall by tidal channels and oilfield canals. Two tidal channels, Little Constance Bayou and Big Constance Bayou, contribute to salt water invasion of the area. Before the canals were built salt water intruded into the area, but at that time fresh water runoff from the north flowed through the area and kept it less saline.

Soils. The soils are of a definite marsh type. They consist of black, gray, and highly organic clays, overlayed by a layer of peat, partly decomposed peat, humus, and dead vegetation three to eighteen inches deep. All of this is covered partially to completely by a plant root system one to six inches deep. Mud flats in unvegetated areas in the same general region are subject to shrinking and cracking in dry periods and do not represent the type of soil on which burns were made.

Vegetation. The dominant vegetation in the study area was wire grass, *Spartina Patens.* The vegetative composition of the immediate study area was about 90 per cent *Spartina patens,* and 10 per cent *Distichlis spicata.* Rockefeller Wildlife Refuge as a whole, outside the impounded areas, is a *Spartina patens* marsh, but in varying degrees of percentage composition. A complete description of the vegetive cover of Rockefeller Refuge is given in Louisiana Wild Life and Fisheries Commission's Special Report on Rockefeller Refuge (1959). A description on the study area prior to 1930, was obtained from Mr. Alcie Theriot, a local land owner and trapper. Mr. Theriot began trapping this land in 1925. He stated that at that time the site on which the study area was located was a fresh to brackish marsh. He related that the emergent vegetation consisted mainly of cattail *(Typha spp.)*, sawgrass *(Caladium jamaicense)*, bullwhip *(Scirpus californicus)*, and leafy three cornered grass *(Scirpus robustus)*.

Climate. The study area is in the semi-tropical zone of the United States and is very humid. The average rainfall for Cameron Parish is 52.91 inches per year.

FIELD PROCEDURE

Six separate burns, each greater than 75 acres in size, were made on the study area. Five burns were made in 1960. The first burn was made on October 8; the second burn was made on October 22; the third burn was made on November 11; the fourth burn was made on November 25; and the fifth burn was made on December 3. The first five burns did not have a vegetated control, but on the sixth burn a vegetated control was established. The sixth burn was made on February 1, 1961. The areas that were to be burned were selected for homogeneity and density of *Spartina patens* to eliminate variations that might result because of differences in stands of vegetation. The following field procedures were followed in measuring the influences of different factors in marsh fires.

Air Temperature. This was taken using a standard mercury bulb thermometer with a -10° F. to 220° F. scale. One temperature reading was taken in shade of vegetation and one was taken in an open area in the sunlight about three feet above ground level.

Soil Temperature. The soil temperature was determined by inserting a standard mercury bulb soil thermometer in the soil to a depth of 1.8 to 2.0 inches. One reading was taken in the shade of vegetation and one in direct sunlight on an unvegetated spot within the area to be burned. Soil temperatures were checked before and after each burn.

Water Samples. A composite water sample was obtained by collecting four ounces of water in five different places and mixing them in one large container. Samples were taken only when free water was present on the burned areas. They were collected in the same manner before and after each burn.

Soil Samples. Five samples of soil, four inches in diameter and three inches deep were taken at random on the area to be burned. They were placed in a large waxed cardboard container and mixed to form one composite sample. Soil samples were collected in this manner immediately before and after each burn. Additional samples were collected in the same manner 10, 26, and 49 days after the burn.

Vegetation Samples. Five vegetation samples were taken from square foot quadrats immediately prior to burning. The measuring quadrat was made from a one-fourth inch diameter brass brazing rod and was open on one side to facilitate its insertion in the dense vegetation at ground level. After it was placed at the base of the vegetation, the fourth side was added to form the complete quadrat. The vegetation was then clipped at ground level and placed in plastic bags, labeled and sealed. Height of vegetation was determined by measuring its natural height at five random stations on the burn area. Most of the vegetation had been blown over. Maximum height was measured by extending the vegetation to its maximum length.

Rate of Forward Spread of Fire. Five 1 x 2 inch fire resistant stakes six feet in height were placed 25 feet apart in a line parallel to and in the estimated path of the fire. The forward speed of the fire was measured by noting the time required for the flames to travel between the stakes.

Wind Direction and Velocity. Wind measurements were taken by using a small plastic anomometer made by the Dwyer Manufacturing Company, Chicago, Illinois. Measurements of wind velocity were made for 10 to 15 minutes just prior to the time of burning and during the actual burn and recorded in miles per hour. Wind direction was determined by checking with a compass prior to and during each burn.

Fenner-Bentley Soil Pyrometer. A small pyrometer designed by Fenner and Bentley (1960), of the United States Forest Service, to measure the penetration of heat into soil from forest and brush fires was used for heat measurements. The basic principle of the pyrometer was the use of thermal lacquers of specific melting points to determine temperatures. The lacquer, Tempillaq, was obtained from the Fisher Scientific Company, St. Louis, Missouri. Tempillaq was available in 90 different melting ranges from 125° to 2400°F. The pyrometer was constructed by painting stripes of the desired temperature lacquer on 1/32 inch-thick asbestos paper; in this case the asbestos paper was cut into 3 x 3 inch squares and painted with 1/10 inch wide lacquer stripes. A sheet of .004-.006 inch thick mica was stapled to the lacquered side of the asbestos sheet. This fusion pyrometer was placed in the soil by making a small perpendicular slit in the ground and inserting it so that the top of the card was at ground level. The slit was closed by inserting a small spade about six inches from it and applying pressure. Three fusion pyrometers, spaced 25 feet apart were placed in a line perpendicular to the path of each fire. The soil pyrometers were located after the burn by the aid of wire flags placed next to them. They were carefully extracted and placed in envelopes and carried to the laboratory for later study. The temperature stripes used in this study ranged from 200°F to 600°F.

Wooden Stake Fusion Pyrometer. A modification of the Fenner-Bentley fusion soil pyrometer was constructed in a manner similar to the small fusion pyrometer except that it was 36 inches long by three inches wide. It was stapled to a 1x3 inch fire resistant six-foot long stake. Estimated minimum to maximum temperature stripes of 250° to 1600°F were lacquered on the asbestos paper. They were placed at three stations perpendicular to the path of the fire and 25 feet apart. The lacquered side which faced the oncoming fire was constructed to record a stratified measurement of fire temperatures from ground level to three feet high. Since these stakes were six feet high, they were easy to locate after the fire. They were pulled from the ground and carefully transported from the burn area to the laboratory where the fusion points could be determined with the aid of a hand lens.

Actual Lighting of the Fire. Fires were started by lighting small patches of vegetation 10 to 15 feet apart along a 200 ft. line perpendicular to the expected path of the fire. All fires were lit on the upwind side of the instrument area. They were started about 150 feet from the nearest recording instrument to insure a normal temperature by the time the fire reached the pyrometers. The instrument areas were only about one-half acre in size. The ultimate size of test fires depended on natural bayous or mud flats that acted as fire barriers.

Ash Samples. Samples of accumulated ash deposits were taken in the burned area. They were collected at random by carefully filling a six-ounce measuring cup at each of the five stations and combining them into one sample in a waxed quart container.

Installation of Taylor Model 791 Dual Remote Recording Thermometer. Immediately after burning a special recording thermometer was installed at the site of a burn. It had a 10-foot remote cable and soil thermocouple which permitted continuous recording of soil temperatures on one scale of the chart and another thermocouple that permitted recording of air temperatures. It was mounted six feet high on a special steel platform over the burn area. The soil thermocouple was inserted one-inch below the blackened surface and the air thermocouple was placed so that the sun could not shine on it.

LABORATORY PROCEDURE

Soil Samples. The two composite soil samples from each burn were analyzed by the Louisiana State University Soil Testing Laboratory in Baton Rouge, Louisiana. Other soil samples were collected on each of the burns 10, 26, and 49 days after each fire. They were analyzed by the soils laboratory to determine changes in the concentration of nutrients.

The presence of phosphorus was determined by colorimetric analysis using a Perkin-Elmer flame photometer. It was extracted according to

Bray and Kurtz (1945), with the exception that a 1:20 ratio (weight soil:volume extracting solution) and a 15 minute shaking time were used. Quantitative determination was made according to Troug and Meyer (1929), with the exception that 5 mls. of saturated boric acid were added in the color development step to avoid fluoride interference. Bray's No. 2 extracting solution was used (.1 Normal HCl-0.03 Normal NH_4F).

The presence of sodium, potassium, calcium, and magnesium in the soil were determined by the use of a Perkin-Elmer Flame Photometer. These elements were extracted using 0.1 Normal HCl, a soil-extracting solution ratio of 1:20 and a shaking time of 15 minutes. This was a modification of a method described by Spurway and Lawton (1949).

Potassium, sodium, and calcium were determined quantitatively by using a Perkin-Elmer flame photometer with lithium as an internal standard. Air-propane gas was burned with sodium and potassium, and air-acetylene gas was burned with calcium.

Magnesium was determined quantitatively by the thiazole or Clayton yellow method described by Mehlick (1956).

The pH was determined by using a Beckman model H-2 meter. A soil-water ratio of 1:1 was allowed to stand for 24 hours before making the measurement (Chapman, et. al, 1941).

Total salts were determined by directions issued by the Association of Official Agriculture Chemists (1955).

Ash Samples. Ash samples were analyzed by the Soils Testing Laboratory at Louisiana State University in Baton Rouge, Louisiana. Phosphorus, sodium, potassium, calcium, magnesium, chlorides, and pH were determined in the same manner as for soils.

Water Samples. Water samples were analyzed by the Louisiana Wild Life and Fisheries Commission Water Pollution Laboratory at Baton Rouge, Louisiana. All samples were analyzed according to directions issued by the American Public Health Association (1955).

Potassium and sodium contents of the water samples were determined by flame photometry on the Beckman Model DU Quartz Spectrometer. Per cent transmission of each of these elements was recorded.

Chlorinity of water samples was determined by volumetric quantitative analysis. Mercuric nitrate was used as the titrant along with an indicator at a controlled equal pH. Chlorinity was determined in ppm from the amount of titrant required to turn the sample a definite violet color.

The pH of the water sample was determined by using a Beckman electric pH meter.

Alkalinity of the water samples was determined by titrating with a standard acid with an equivalence point of 4.5. Alkalinity values were reported in ppm and represent the total amount of bicarbonate, carbonate, and hydroxide ions present.

Hardness of the water samples was determined by the EDAT titration method. Hardness was expressed in ppm as the equivalent of $CaCo_3$ and $MgCO_3$ concentration.

Specific conductance of the water samples was determined by using a Fisher Titrimeter arranged to form a Wheatstone Bridge circuit. The conductance is expressed in mil mhos at 25° C.

Moisture of Vegetation. Each vegetation sample was weighed separately and the weight recorded. The plastic bags containing the vegetation were opened and placed in a 1500 watt Barkel Drying oven for a period of one week at 175° - 180°F. At the end of this drying period they were reweighed. The per cent of moisture in the vegetation was determined by subtracting the dry weight of each sample from the wet weight, and dividing the difference by the wet weight to give the per cent of moisture in the vegetation sample. Moisture contents of five samples were averaged to give the per cent moisture at the time of burning.

Density of Vegetation. After the moisture of the vegetation was determined by differential weighing, the vegetation samples were taken one at a time and a stem count made of each of the five samples. The green stems were counted separately from the dead stems to give the amount of "rough" (dry stems) present at the time of the burn. The average pounds per acre of vegetation was computed from the dry weight of five samples for each burn area.

Salinity of Vegetation. Vegetation samples were analyzed for chlorides by mercuric nitrate titration. To perform this test in the laboratory, the composite sample of vegetation taken in the field for salinity determination was cut up into one-inch lengths. Fifty grams of the cuttings were placed in a 500 cc beaker with 300 cc of distilled water. This was allowed to stand for 12 hours and then filtered. The filtrate was then measured for chlorinity by titrating with mercuric nitrate. Chlorinity was expressed in ppm. It is believed that this method had not been used before this study.

Fenner-Bentley Fusion Soil Pyrometer. This fusion pyrometer was examined in the laboratory under a 10 power lens to find the fusion points on the different Tempillaq lines. The distance from the top of a card on a particular temperature line to its fusion point was measured in tenths of an inch to determine heat penetration into the soil.

Wooden Stake Fusion Pyrometers. These three-foot fusion pyrometers were used to measure the temperature reached in a fire from ground level to a height of three feet. Before reading the pyrometer in the laboratory, the mica sheeting had to be removed because it was charred during the fire. The different temperature stripes were measured at points of fusion and distance above ground recorded.

DISCUSSION OF RESULTS

Soil Nutrient Gains After Burning

All soil nutrients that were measured increased in five of the six burns. The most logical explanation for the increase is that the gains were derived from the nutrients present in the vegetation. This was evidenced by the contents of the ash sample as shown in Figure 1. *Spartina patens* belongs to a peculiar group of marsh plants, halophytes, that possess the ability to utilize different concentrations of salt water due to an osmotic regulatory process of the cell walls. Because of this, they can tolerate rapid changes of salinity without being dehydrated or hydrolyzed due to differences in osmotic pressure between the plant and the concentrations of salt in tidal water around it. Thus, this plant receives and uses salt solutions that are spread throughout the plant.[1] This is the source of the mineral nutrients present in the ash after a fire. These elements are normally very high in marsh clays and peats (Table 1). In the present study following burning, except in burn number six, potassium and magnesium were not shown to increase. Since the amounts present represent the optimum levels of the substances as found in agricultural soils, they were not measured above the optimum levels. In all soil samples collected after burning, there was a definite presence of sodium in the flame photometry test for potassium, but a quantitative analysis of sodium was not made due to the complexity of the test. Therefore, in this study the amount of sodium in the soils was not checked. The immediate gain of calcium, phosphorus, chlorides and pH in the soil as compared to average ash content is shown in figure 1. The gain is probably due to the high content of each of these substances derived from the vegetation. The ash samples contained very high levels of calcium, phosphorus, and chlorides. The pH of the ash was also high.

It was stated that, in five of the six burns that were measured, the nutrient content of both the soil and the water increased after a burn. An analysis of the mean difference of the nutrient gain in paired samples of each nutrient was done by the use of the Students "t" test. The test revealed that the calculated "t" value for each nutrient comparison except calcium exceeded the tabular "t" value for probability at the 5 per cent level with five degrees of freedom ($T_{.05} = 2.776$). The calculated "t" value for calcium in the sixth burn was 2.43. If burning had no effect on the nutrient level, then one would expect to get a higher level of nutrients after burning in all six burns only two per cent of the time, since ½ raised to the 6th power equals 1/64 or two per cent. Thus, the probability of getting the consistently higher nutrient values following burning, as in this study, are very small if combustion of plant material containing a high level of mineral nutrients had no effect on the level of nutrients in the soil and water.

[1] Brown, Clair A. 1961. Personal Interview. Professor of Botany, Louisiana State University.

TABLE I.

CALCIUM, POTASSIUM, SODIUM, SODIUM CHLORIDE, AND TOTAL SALT CONTENT FOR CLAY, MUCK AND PEAT SAMPLES FROM THE MARSH AND SWAMP AREAS OF ST. MARY PARISH.

Material	*Location*	*Depth*	*No. of Samples*	*Ca*	*Average milligrams per 100 gms of material* *K*	*Na*	*Total*	*Average NaCL Percent*	*Average Total Salt %*
	Marsh:	Surface	21	34	9	115	158	.33	.54
Clays:		Subsurface	20	26	14	176	216	.35	.72
	Swamp:	Surface	5	6	5	40	51	.08	.15
		Subsurface	4	10	6	68	84	.11	.26
	Marsh:	Surface	29	62	15	182	259	.36	1.11
Mucks:		Subsurface	23	44	15	182	240	.30	.98
	Swamp:	Surface	6	49	6	45	100	.06	.46
		Subsurface	4	28	15	142	187	.21	.80
	Marsh:	Surface	2	101	34	980	1109	2.85	3.27
Peats:		Subsurface	3	35	22	459	515	1.02	1.66
	Swamp:	Surface	3	32	13	301	347	.81	1.17
		Subsurface	2	8	9	110	127	.27	.28

Source: S. A. Lytle and B. N. Driskell. Physical and Chemical Characteristics of the Peats, Mucks and Clays of the Coastal Marsh Area of St. Mary Parish, Louisiana, Louisiana Agricultural Experiment Station Bulletin No. 484, March 1954.

TABLE II.

SOIL NUTRIENT CHANGES IN PPM AND PER CENT GAIN AFTER BURNS. ROCKEFELLER REFUGE, CAMERON PARISH, LOUISIANA, 1960.

	Phosphorus			*Calcium*			*Magnesium*			*Potassium*			*pH*			*Chlorides*		
	*B**	*A***	*Per-cent Gain*	*B*	*A*	*Per-cent Gain*	*B*	*A*	*Per-cent Gain*	*B*	*A*	*Per-cent Gain*	*B*	*A*	*Per-cent Gain*	*B*	*A*	*Per-cent Gain*
1	83.0	200.0	141.0	3413.0	3931.0	15.2	450.0	450.0	0	432.0	432.0	0	4.9	7.5	53.0	5380.0	13880.0	163.3
2	107.0	166.0	55.1	2462.0	4234.0	71.9	450.0	450.0	0	432.0	432.0	0	4.2	7.6	80.9	8850.0	22790.0	157.5
3	89.0	172.0	107.2	4320.0	4984.0	15.4	450.0	450.0	0	432.0	432.0	0	6.2	7.8	25.8	4100.0	16380.0	299.5
4	112.0	184.0	64.3	3160.0	3760.0	18.9	450.0	450.0	0	432.0	432.0	0	5.3	7.2	35.8	4830.0	23650.0	389.6
5	94.0	146.0	55.3	2893.0	4367.0	50.9	450.0	450.0	0	432.0	432.0	0	6.8	7.9	16.2	6460.0	14490.0	124.3
6	153.0	293.0	....	3310.0	3128.0	...	....	....	0	....	....	0	6.1	6.7	...	12700.0	21900.0	....
Average:	106.3	193.5	82.0	3259.6	4067.3	30.5	450.0	450.0	0	432.0	432.0	0	5.6	7.5	33.9	7053.3	18848.3	167.2

*Before.
**After.

Soil Nutrient Decrease

There was a rapid decrease in the original gain from burning in the amount of soil calcium (Figure 2), phosphorus (Figure 3), chloride (Figure 4), and pH (Figure 5). Samples that were collected 10, 26, and 49 days after burning showed a general decrease in the amount of nutrients.

The average amount of calcium found in the five soil samples taken prior to burning was 3259.6 ppm. Immediately after burning it rose to an average of 4067.3 ppm. After an elapse of 10 days, calcium dropped to 3183.0 ppm. At this time the level dropped below the original level of calcium in the soil before the burn. At 26 days after burning it had declined to 2604.5 ppm, and after 49 days it had dropped still lower to 2543.5 ppm. One factor that may have caused the decline was plant regrowth and uptake of nutrients. At the 10 day period, *Spartina patens* had grown to an average height of about 11 inches, 19 inches during the 26 day period, and 23 inches during the 49 day period. The old growth of *Spartina patens* had an average dry weight of 3585.4 pounds per acre. Based on other density studies of *Spartina patens* by the writer, this represented a very dense growth. Because of its maturity, plant growth was slow just prior to the burn with little drain of nutrients. Consequently, there may have been a build up of calcium in the soil after the major growing period. Removal of "rough", higher soil temperatures, and the addition of calcium and other nutrients by the fire, stimulated very rapid new growth. The demands of the new growth may have been very high on the original calcium in the soil as well as on the newly added calcium, thus, a rapid depletion of this element.

Other factors which may have contributed to the reduction of calcium are tidal action and rainfall. There were tides of more than 1.6 feet above mean gulf level during the period of depletion (U.S.Corp. of Engineers, New Orleans, Louisiana (1960-1961). Such tides would have flooded the area from four to six inches deep. Sea water has an average of 4100.0 ppm. CaCL or Ca HCO_3. This weaker concentration of CaCL could have caused depletion by dilution (Sverdrup, *et al.*, 1954). The total rainfall for the period of depletion was 9.8 inches (Rockefeller Refuge rainfall records, 1960-1961). The dilution and runoff would thus carry away some of the calcium which was probably in chloride and hydroxide form, as calcium carbonate is soluble to a very small extent in water (Hutchinson, 1957). Lytle and Driskell (1954) stated that carbonates were not present at all in the surface and subsurface layers of any group of marsh or swamp clays, peats, and mucks in St. Mary Parish; therefore, it is unlikely that they were present on Rockefeller Refuge.

Phosphorus, as shown in Table 2, was present in the soils at a concentration of 106.3 ppm before burning. It rose to 193.5 ppm immediately following the fire, a gain of 82.0 per cent. In 10 days it dropped to 150 ppm; in 26 days to 131.7 ppm, and in 49 days to 119.0 ppm, which was a 85.4 per cent loss of the original gain. There are several possible explanations for this loss which is believed to be a natural occurrence. Phosphorus does not exist in pure form in water, but oxidizes and combines with bases to form phosphates which are among the most important plant foods. The presence of large amounts of calcium in the soil also brings about the release of phosphorus compounds to make them available to plants (Coker, 1954). Thus, accelerated plant growth would be one factor causing a rapid reduction in phosphorus.

Buckman and Brady (1960) stated that with time, changes take place in the reaction products of soluble phosphates and soils. Precipitation of phosphorus occurs in moist soils in a reaction with $CaCo_3$ and Co_2. This leaves less phosphorus near the surface for plant take-up. In sampling soil only the top three inches were extracted. There is a chance that concentrations of phosphorus are located at a greater depth in the soil.

Dilution and runoff of rainfall and tidal waters are other factors that may have contributed to a decrease in phosphorus. The utilization of phosphorus by plankton could account for a decrease.

Soil chlorides were increased 167.2 per cent during the burn. This gain is attributed to the deposition of ash, which had a chloride content of 26670.0 ppm. The chlorides also decreased rapidly after the burn (Figure 4) with 60.7 per cent loss of the original gain in 10 days; a 57.5

per cent loss in 26 days; and a 50.6 per cent loss in 49 days. Although not measured, most of this loss is attributed to dilution from rainfall, tidal action, and plant uptake.

The chloride content of the soil surface was higher than the subsurface soil after a fire. The surface concentration averaged 11795.0 ppm; the subsurface chlorides were 4431.3 ppm (Rockefeller Refuge soil test, 1959). Due to osmotic pressure difference, the moisture in the subsoil would have a tendency to move up, carrying subsurface chlorides to the surface. There is a vertical movement of the chlorides in soils to reach a point of equilibrium. Redfield (1958) stated that the distribution of chlorides suggests a move towards a steady state due to a balance between a downward movement of salt water by some form of eddy diffusion and an upward movement of ground water. This may account for almost equal ppm before the burn and 49 days after the burn.

An increase in soil pH is the normal occurrence after most burns due to the high alkalinity of the ash. Burns (1952) stated in his conclusions from reviews of literature that burning affects chemical properties of the upper layers of the mineral soils by increasing the pH. The decrease in pH following a burn may be a result of the reaction of the higher acid of the subsoils against the basal effect of the surface of the soil. Since the subsoil seems to contain a higher amount of acid as shown by Lytle and Driskell (1954), the basic effect of the surface would tend to be normalized and then finally acidized.

Although nitrogen content was not measured in the soil during this study, it is felt by the author that nitrogen should be discussed. Willis (1961) states that nitrogen is lost by volatilization in forest fires. Thus, it is assumed that it is lost in grass fires. It is understood that the source of the soil nitrogen is the organic matter. If the organic matter is burned, some nitrous oxide might remain as a residue and be washed into the soil by water. Thus, there would be a temporary increase, but the major part of nitrogen in the organic matter would be lost in volatilization during the burning process.

Water Nutrient Gain and Decrease

Water samples immediately after the burn showed an increase in sodium, potassium, chlorinity, total alkalinity, and pH (Table 3). The source of this gain is attributed to the elements in the ash. The decrease of these substances and pH after a burn was evident, but could not be measured accurately because limited free water prevented a uniform method of sampling. If water samples had been taken by making small catch holes, they would have represented a soil extract and not a true free water sample. The water that was measured for chemical content before and after burns was available in very small holes or puddles of six inches to two feet in diameter and approximately three inches deep. Only once did the water completely cover the marsh and that was for only a five to six hour period on the 25th of November. For this reason water could not be considered in the same manner as in lakes and larger bodies of water to explain the losses of the added nutrients. The samples from these puddles more nearly represented a bottom deposit. Such things as phorphorus precipitation in free water, as explained by Welch (1952), would probably not apply in this case.

Vegetation

Vegetation samples were found to have an average dry weight of 3584.6 pounds per acre. The density of stems averaged 151.4 per square foot. Of these stems 53.2 per cent were living and 46.8 per cent were dead. The average length of the stems was 3.3 feet but because of lodging the average height of the vegetation was only 2.2 feet. The chloride content of the vegetation was determined to be 12,610.0 ppm. The salts in the vegetation accounted for the rise in chlorides in the soil after the burn (Table IV).

Wind Effect

The forward spread of the fire varied only 1.1 feet per minute from the slowest to the fastest rate during five fires. Wind velocity varied 12 miles per hour from slowest velocity to fastest (Table V). The average rate of forward spread was .23 feet per minute per mile an hour of wind velocity.

The influence of the relative values of wind velocity, plant density, and moisture content of vegetation on rate of forward spread is shown

TABLE III.

CHEMICAL CHANGES OCCURRING IN WATER SAMPLES BEFORE BURN AS COMPARED TO WATER SAMPLES AFTER BURN. ROCKEFELLER REFUSE, CAMERON PARISH, LOUISIANA, 1960.

Burn	Sodium			Potassium			Chlorinity			Total alkalinity			pH		
	B* ppm	A**	Per-cent Gain	B	A	Per-cent Gain	B	A	Per-cent Gain	B	A	Per-cent Gain	B	A	Per-cent Gain
1.	1850.0	1950.0	5.4	110.0	137.0	24.5	3273.0	3422.0	4.5	62.0	425.0	591.9	7.1	7.2	1.4
2.	1734.0	2165.0	24.8	117.0	152.0	29.9	3840.0	4028.0	4.9	84.0	463.0	451.2	6.8	7.2	5.9
3.	1910.0	2240.0	17.3	126.0	142.0	12.7	4175.0	4486.0	7.4	57.0	480.0	742.1	6.3	7.4	17.5
4.	2080.0	2276.0	9.4	138.0	156.0	13.0	3524.0	4153.0	17.8	49.0	367.0	648.9	5.9	7.1	20.3
5.	1835.0	1984.0	8.1	706.0	128.0	20.7	3127.0	3329.0	6.4	73.0	408.0	458.9	6.6	7.1	7.6
Average	1881.8	2123.0	13.0	119.4	143.0	20.1	3587.8	3883.6	8.2	65.0	428.6	559.4	6.5	7.2	10.8

*Before.
**After.

in Table V. The fuel which averaged 3584.6 pounds per acre had an average moisture content of 51.3 per cent. Wind speed averaged 6.9 miles an hour and the rate of forward movement of the fire averaged 1.6 feet per minute in all the fires. Wind effect was not measured in burn number six.

Burn Number 6

Burn measurements from this fire were compared with measurements from a vegetated control. The erratic results shown in Figures 6 and 8, are attributed to flooding of the burn site by tidal waters. At times when the burn area and vegetated control were re-sampled there was from five to six inches of tidal water standing on them. Phosphorus (Figure 7), showed the same trend in burn six as in the five previous burns. It is evident from this that concentrations of nutrients are greatly affected by tidal actions.

Temperatures

Air temperature on areas before burns averaged 70.8°F. in the sun and 70.4°F. in the shade of vegetation. The highest temperature of the air before a burn was 91°F. in the sun and 98°F. on the soil surface in the sun. The lowest air temperature in the shade of vegetation was 60°F. Air temperatures after burns showed no appreciable rise over pre-burn air temperatures.

Soil temperatures averaged 70.1°F. in open unvegetated areas and in direct sunlight. In the shade of vegetation the average temperature was 68.6°F. Soil temperatures after burning averaged 72.6°F., which was a rise of 1.4°F. This rise in temperature is due to the first burn which was conducted when the water level was five inches below marsh level. Because of the lack of moisture in the soil, the soil temperature rose from an average of 95.5°F. before the burn to 106°F. in the soil after the burn. Heat penetration into the soil on this one burn was registered on a Fenner-Bentley soil fusion pyrometer as follows: 200°F. penetrated to a depth of 1.10 inches; 350°F. penetrated to a depth of 0.9 to 1.1 inches; 450°F. penetrated to a depth of .55 inches; and 600°F. penetrated to a depth of .1 inches. This is the only reading obtained on the Fenner-Bentley fusion pyrometer. It was found that this soil pyrometer did not register in wet soils. To further check if soil temperatures rose

TABLE IV.

VEGETATION, DENSITY, PER CENT MOISTURE, DEAD STEM: GREEN STEM RATIO, AND VEGETATION HEIGHTS ON FIVE BURN AREAS. ROCKEFELLER REFUGE, CAMERON PARISH, LOUISIANA, 1960.

Lbs./Acre Dry Weight	*Percent Moisture*	*No. of Green Stems*	*No. of Dead Stems*	*Vegetation Height in ft.*
3450.0	56.3	56.0	67.0	2.4-3.3
3215.0	48.7	63.0	87.0	2.2-3.9
3652.0	32.2	119.0	42.0	2.1-3.5
4360.0	61.2	76.0	106.0	2.0-3.2
3350.0	58.1	89.0	52.0	2.6-3.2
Average: 3585.4	51.3	80.6	70.8	2.2-3.4

TABLE V.

POUNDS OF FUEL, PER CENT MOISTURE CONTENT OF VEGETATION, WIND SPEED, AND SPREAD OF FIRE, OBSERVED ON FIVE FIRES ON ROCKEFELLER REFUGE, CAMERON PARISH, LOUISIANA 1960.

Burn	*Fuel Lbs./Acre*	*Percent Moisture Content*	*Wind m.p.h.*	*Spread f.p.m.**
1	3450.0	56.3	8.0	1.8
2	3215.0	48.7	7.0	1.1
3	3652.0	32.2	5.0	1.3
4	4360.0	61.2	9.5	2.2
5	3250.0	58.1	5.0	1.9
Average	3585.4	51.3	6.9	1.6

*Feet per minute.

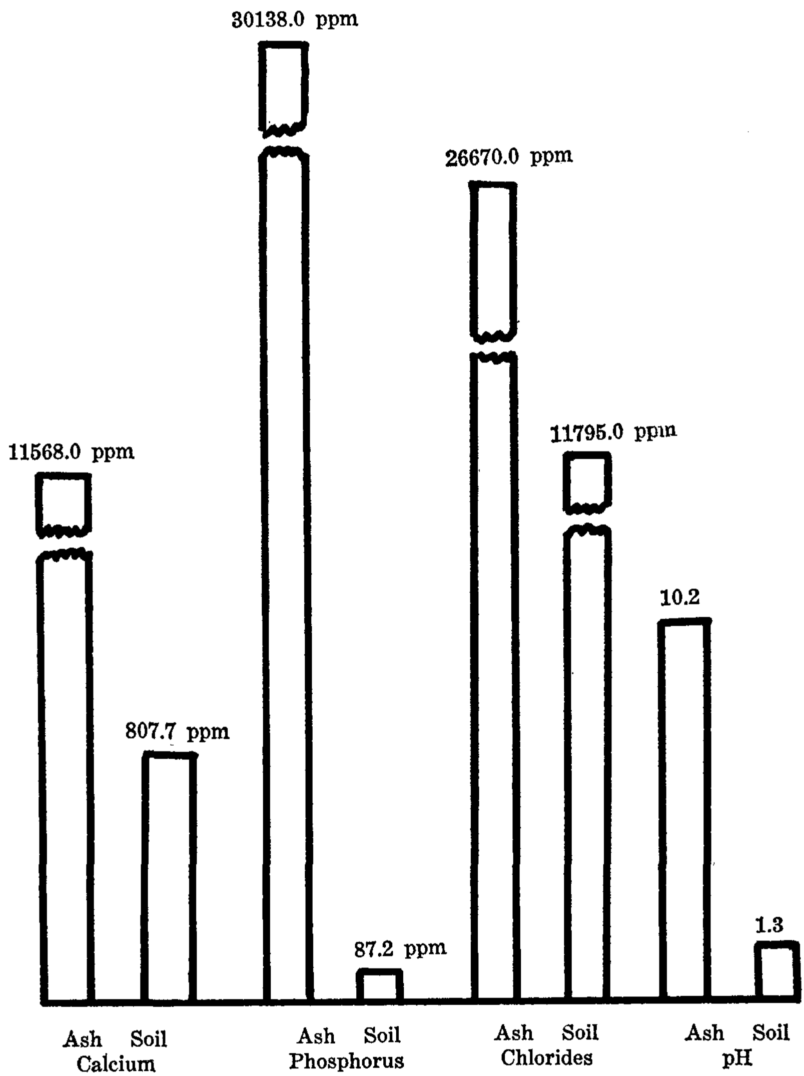

Figure 1. Chemical composition and pH of ash in comparison to increase of nutrients and pH in the soil immediately after burning. Rockefeller Refuge, Cameron Parish, Louisiana.

at the time of burning, a maximum high registering thermometer was buried ½" under the soil during subsequent burns and no rise in temperature was recorded. Therefore, it is assumed that no rise in soil temperature occurs in marsh fires if the water is at marsh level or more.

Stake fusion pyrometers were used to record vertical air temperatures of fires during burns. A total of 12 were installed on the areas to be burned. Because of the charring effect of the fire only one stake pyrometer could be read. The temperature stratification was as follows: on the 250°F. line, ¼ inch to 36 inches above ground was melted; on the 400°F. line, ½ inch to 14 inches was melted; on the 600°F. line, 2.5 inches to 8.5 inches was melted; on the 700°F. line, from 3 inches to 7.2 inches was melted; on the 900°F. line, from 5 to 6 inches was melted;

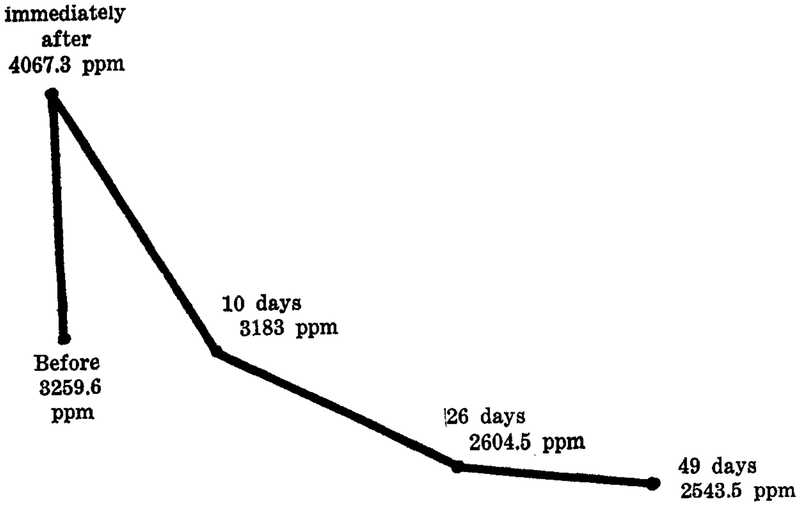

Figure 2. Average soil calcium in ppm immediately before, immediately after, and 10, 26, and 49 days after burning on six burns. Rockefeller Refuge, Cameron Parish, Louisiana.

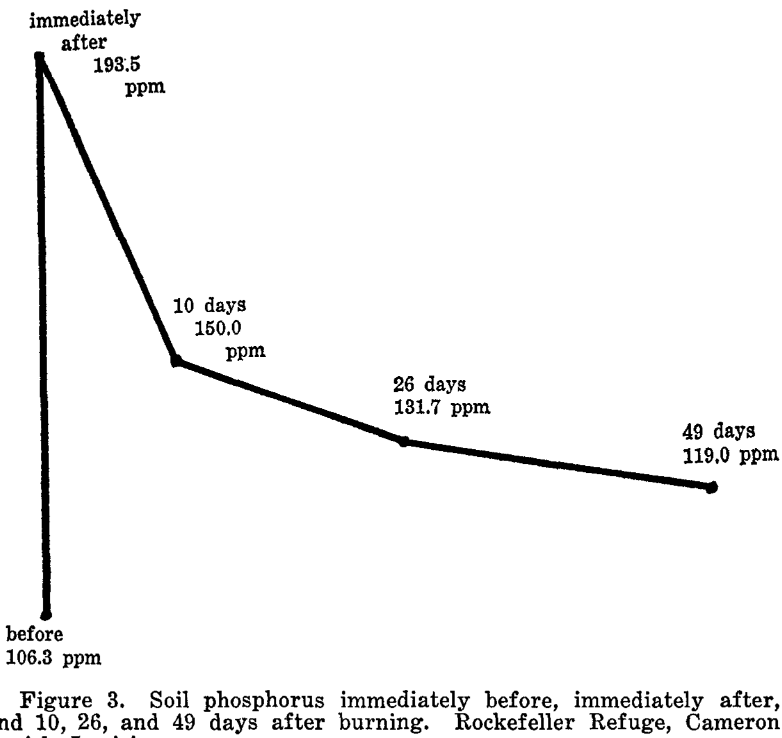

Figure 3. Soil phosphorus immediately before, immediately after, and 10, 26, and 49 days after burning. Rockefeller Refuge, Cameron Parish, Louisiana.

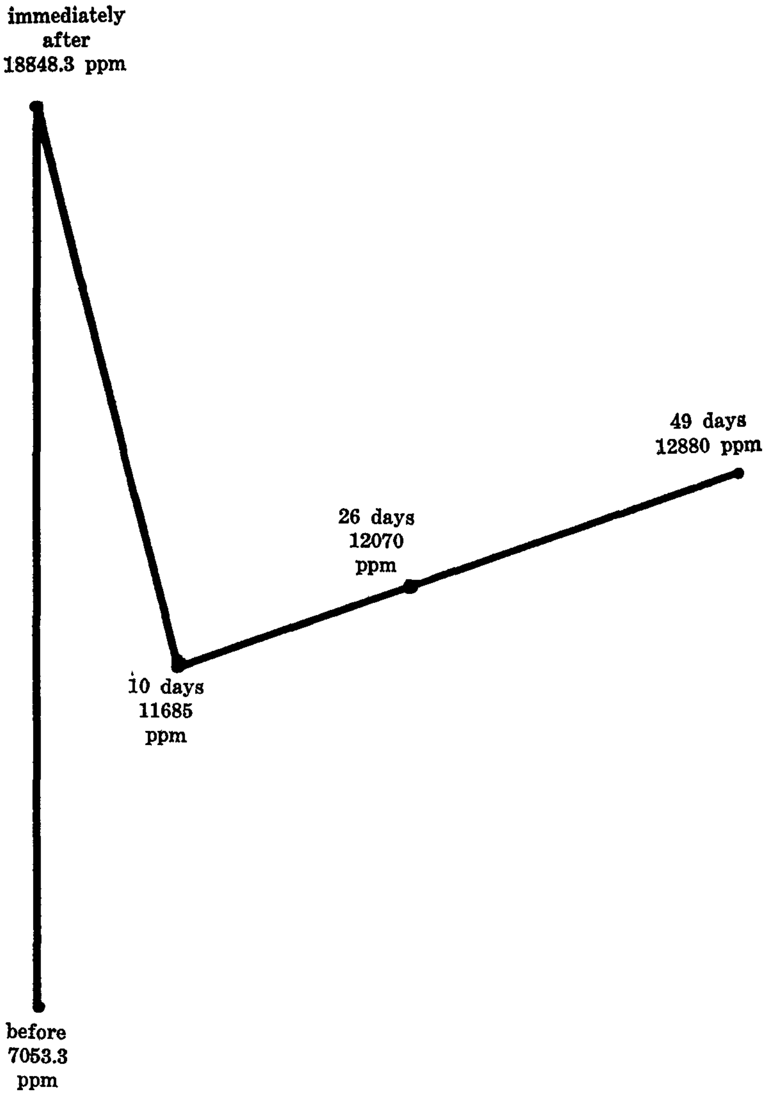

Figure 4. Soil chlorides immediately before, immediately after, and 10, 26, and 49 days after burning. Rockefeller Refuge, Cameron Parish, Louisiana.

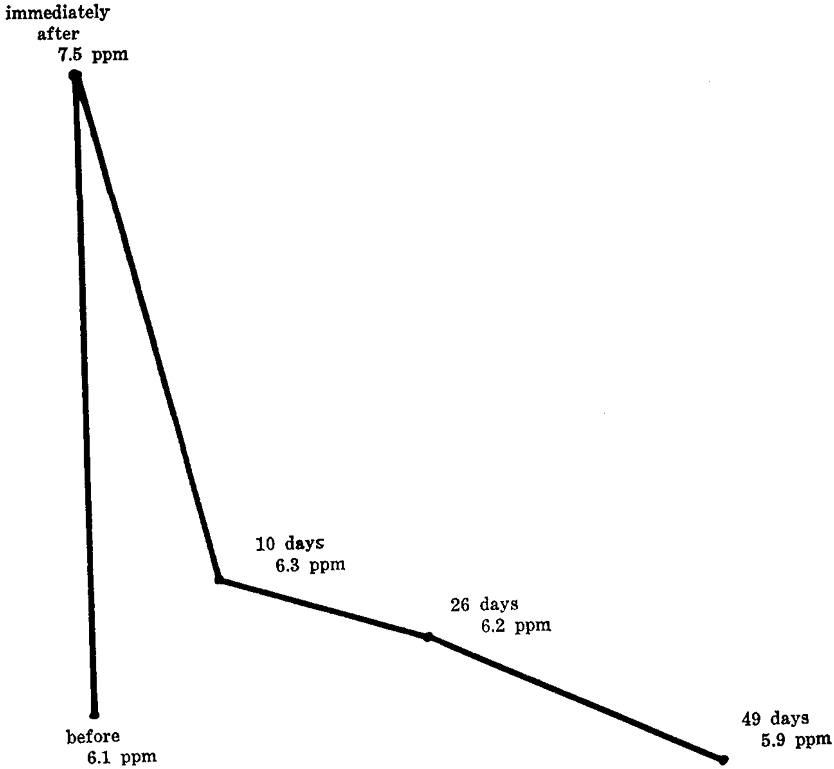

Figure 5. Soil pH before, immediately after, and 10, 26, and 49 days after burning. Rockefeller Refuge, Cameron Parish, Louisiana.

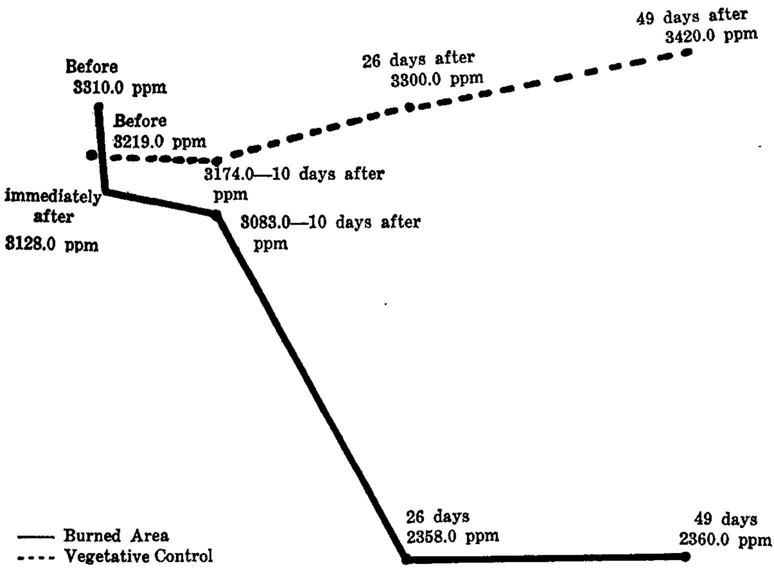

Figure 6. Calcium in burn No. 6, immediately before, immediately after, and 10, 26, and 49 days following the burn as compared to an unburned vegetated control. Rockefeller Refuge, Cameron Parish, Louisiana, 1960.

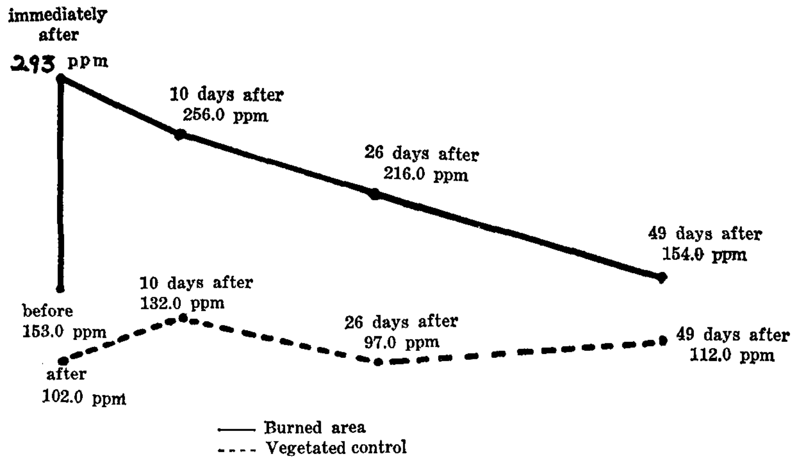

Figure 7: Phosphorus in burn No. 6, immediately before, immediately after, and 10, 26, and 49 days following the burn as compared to an unburned vegetated control. Rockefeller Refuge, Cameron Parish, Louisiana, 1960.

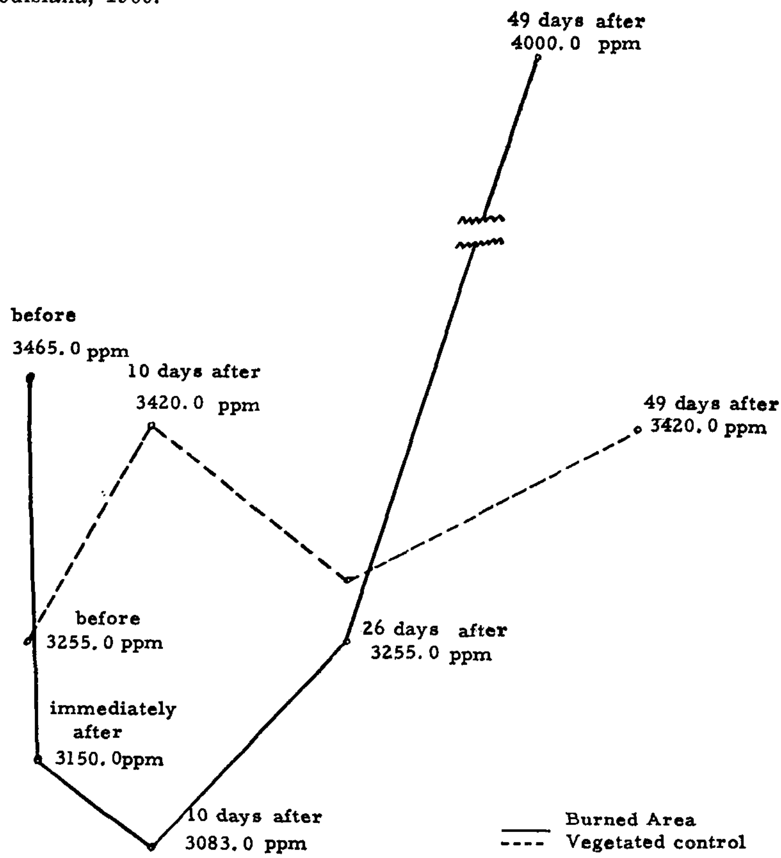

Figure 8: Magnesium in burn No. 6, immediately before, immediately after, and 10, 26, and 49 days following the burn as compared to an unburned vegetated control. Rockefeller Refuge, Cameron Parish, Louisiana, 1960.

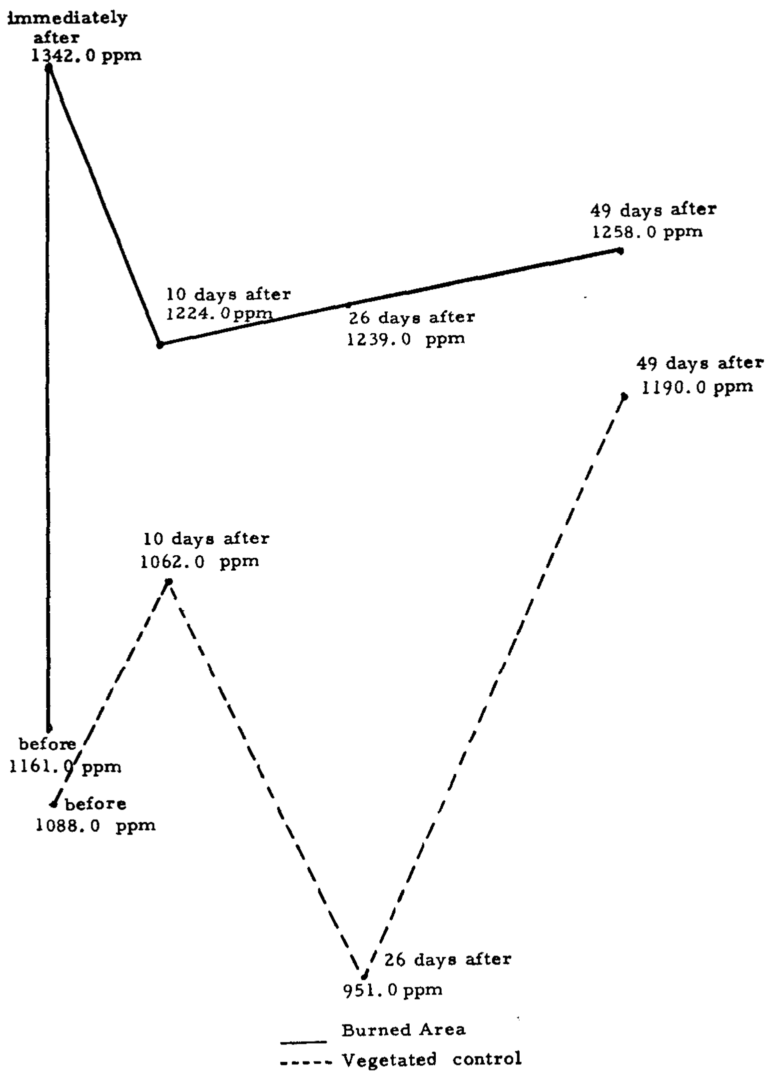

Figure 9: Potassium in burn No. 6, immediately before, immediately after, and 10, 26, and 49 days following the burn as compared to an un-unburned vegetated control. Rockefeller Refuge, Cameron Parish, Louisiana, *1960.*

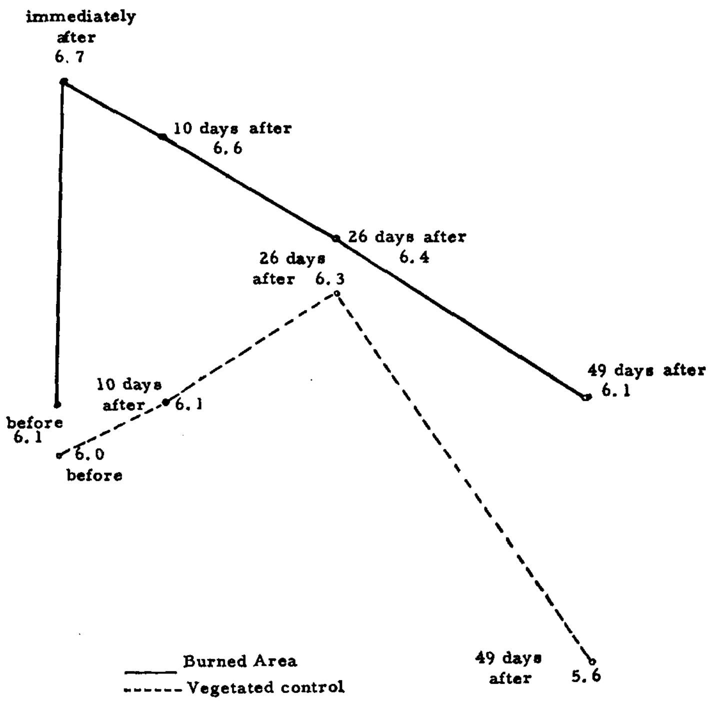

Figure 10: Soil pH in burn No. 6, immediately before, immediately after, and 10, 26, and 49 days following the burn as compared to an unburned vegetated control. Rockefeller Refuge. Cameron Parish, Louisiana, 1960.

and on the 1200°F. line, from 6 inches above ground to 9 inches above ground was melted. This indicated a rather erratic pattern in the functioning of the pyrometer, or an erratic pattern in the fire temperatures. One thing noted on all 12 stake pyrometers was an area from ¼ to 2½ inches above ground that did not register any temperature. It is believed that some sort of vapor cushion was established between the heat of the fire and the water in or over the soil. This stake pyrometer was not used on the first burn with the minus five inch water level as it had not been constructed.

Soil on the blackened burn area absorbed more heat than the soil in vegetated areas (Table VI). The spread between maximum air temperatures and maximum soil temperatures on the burned areas during the day averaged 5.8°F. and the spread at night averaged 2.14°F. which showed it still had heat retained to maintain a spread at night time.

The vegetated area during the day had an average spread between maximum air and soil temperature of 11.14°F. The spread between maximum air and maximum soil temperature at night averaged 1.40°F. (Table VI). Had the Taylor remote recording thermometer been installed on the burn area on the second or third day after the burn, the difference between day maximum air temperature and maximum soil temperature would have been less. This was because the soil did not have time to warm up on the first day, as indicated in Table VI. Direct temperature reading comparison could not be applied in this case as only one remote recorder was available. It had to be installed on burned and vegetated areas at different times.

MANAGEMENT APPLICATION

Burning affects two things greatly; one is vegetation and the other is wildlife.

The data presented show that nutrients tied up in vegetation are released and added to the soil and water when the marsh is burned. In marsh management, it is important to consider the time to burn. If perpetuation of the same stand of vegetation is desirable, then a burn just prior to the spring growing season would be most beneficial. To time the burn correctly one would have to know when to expect the higest spring tides. If a burn were made just prior to a high spring tide, then most of the nutrients would be lost due to tidal action. Should the burn be made too late in the spring, there would be a chance of injury to nesting ducks. In summer or early fall burning one must consider the possibility of thousands of blue geese *(Chen caerulescens)* and snow geese (Chen hyperborea) flocking to burns to seek out plant roots as food. Geese sometimes eliminate plant root stocks, thereby preventing regrowth of the stand. If fire is set in the summer, the vegetation is usually too succulent to insure a good burn. There may also be a chance of destroying some late nesting mottled ducks (Anas fulvigula maculosa).

TABLE VI.

SPREAD IN TEMPERATURE BETWEEN AIR AND SOIL ON BURNED AREA AND AIR AND SOIL TEMPERATURE ON AN UNBURNED AREA AS RECORDED BY THE TAYLOR 791 DUAL SOIL-AIR TEMPERATURE RECORDER, ROCKEFELLER REFUGE, CAMERON PARISH LOUISIANA, 1960.

Day	*3 P.M.* Burned °F.	Unburned °F.	*2 A.M.* Burned °F.	Unburned °F.
1st.	14.0	18.0	2.0	0.0
2nd.	8.0	14.0	4.0	0.0
3rd.	2.0	14.0	2.0	4.0
4th.	6.0	6.0	3.0	4.0
5th.	0.0	10.0	2.0	0.0
6th.	6.0	8.0	2.0	2.0
7th.	5.0	8.0	0.0	0.0
Average Temperature	5.8	11.1	2.1	1.4

Regardless of the time of year, if a change in marsh type from *Spartina patens* to *Scirpus spp.* is wanted, then one must burn when the marsh is dry. This usually burns deep enough to kill, or set back the roots of the dominant vegetation *Spartina patens* and allows the subclimax plants, *Scirpus olneyi* and *Scirpus robustus*, to gain an advantage due to the reduction of competition. If one should burn in a flooded marsh, then the nutrients would be carried away by tidal waters, to a great extent, and the new growth of vegetation would benefit very little from the burn.

SUMMARY

This study was designed as a pilot type research problem on marsh burning. Objectives were to devise methods of measuring marsh fires and of evaluating them; to measure factors influencing marsh burns; and to measure some of the effects of marsh burns.

Six burns were measured on Rockefeller Refuge, Cameron Parish, Louisiana. It was found that the Fenner-Bentley Soil fusion pyrometer did not work in wet soils. A modification of the Fenner-Bentley pyrometer, which was designed to measure temperature stratification, did not work well due to the blackening effect of the fire. This study revealed that field measurement of fire temperatures is a very difficult problem. Temperature measurements above ground level were quite variable during burning.

Water samples after a burn showed an increase in pH, Sodium, potassium, chlorinity, and total alkalinity. Soil temperatures on the burned areas were consistently higher than on adjacent vegetated areas. Water samples were not representative of free water samples, but were more representative of soil extracts.

Soil temperatures did not rise during marsh fires if the water level was at marsh level or higher.

It was determined that the nutrient gain after a burn was a result of the deposition of ash.

In all cases the following values on marsh burns were increased: soil pH, chlorinity, phosphorus and potassium. Calcium increased on five of six burns. It was found that most of the increases in these substances were greatly depleted in 49 days after a burn.

It was concluded that to reduce undersirable plant species in a marsh the water level in the marsh must be below the soil level to insure root damage. If the marsh is burned when the soil is wet, as it is in many cases, the only results would be immediate addition of nutrients to the soil, thus promoting growth of the undesirable plant. This short period of added nutrition is depleted rapidly by tidal action, rainfall and regrowth.

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ESTIMATING THE NUMBER OF MARKED ANIMALS WHICH HAVE RETAINED THEIR IDENTITY FROM MULTIPLE MARKED ANIMALS AND ITS APPLICATION TO THE PETERSEN METHOD

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ABSTRACT

In order to make an estimate of the size of a population of animals at a given time by the Petersen method, use is made of a sample of the fraction of marked animals in the population. However, if some of the animals originally marked lose their marks and thus can not be identified in the sample, a Petersen type estimate will be biased, the magnitude of the bias depending upon the proportion of animals retaining their identity. If an estimate can be made of the animals which have retained their identity at a given time, it is possible to make corrections for this bias. This report presents formulas for estimating the number of marked animals which have retained their identity at a given time from multiple marked animals and shows their derivation, shows their application to the Petersen method, discusses the necessary conditions for them to apply, discusses the errors associated with such estimates and shows how confidence limits can be determined.