EFFECTS OF VARIOUS LEVELS OF CRUDE OIL ON OLNEY BULRUSH (*Scirpus olneyi*) AND MARSHHAY CORDGRASS (*Spartina patens*)[1]

by

JAMES L. GEBHART

Kansas Forestry, Fish and Game Commission,
Independence

and

ROBERT H. CHABRECK[2]

School of Forestry and Wildlife Management
Louisiana State University, Baton Rouge

ABSTRACT

A tank study was conducted to determine the effects of various concentrations of crude oil on brackish marsh plants. *Scirpus olneyi* and *Spartina patens* were grown in tanks and subjected to a light and a heavy crude oil at four concentrations and four water levels over an 8.5-month period. Growth and survival of plants were determined monthly. A fluctuating water level (+5 to −5cm) with 80 parts per thousand (ppt) of heavy crude oil was the treatment most detrimental to *S. olneyi*. Crude oil enhanced growth and survival of *S. olneyi* at a water level of +5cm above the soil surface. Growth increased as oil concentrations increased and was greater for heavy oil than for light oil of equal concentrations. For *S. patens* treated with crude oils, a fluctuating water level (+5 to −5cm) and a +5cm water level were the most detrimental. High oil concentrations were detrimental to *S. patens* at water levels of −5cm and 0cm. Damage to *S. patens* was more severe for heavy oil than for light oil. As oil concentrations increased, damage was more evident.

INTRODUCTION

Oil is periodically spilled in the coastal area as a result of pipeline breaks, well blow-outs, and barge ruptures. The oil may be spilled directly into the marsh or in the estuarine areas adjacent to the marsh and carried inland by currents, tides, and winds. Most previous studies on oil spills have dealt with spills on open water, and very little is known about the effects of spills on marsh plants.

Observations by Baker (1971) and Cowell (1971) indicated that there is little long-term vegetative damage to perennial species but annual species and seedlings rarely recover when oiled. This is due to the fact that recovery of oiled vegetation is by new growth, not by recovery of oiled parts. There is evidence that marshes recover well from single oil spills. Badly oiled marshes studied by Chabreck (1973) and Cowell (1973) appeared completely recovered two years after the spill. Baker (1971) reported that plants oiled in May had recovered by September, and that plants oiled in August had recovered by October.

Because of the high value of plants to the overall productivity of Louisiana marshes and the lack of information on the effects of oil spills on plants, a study was undertaken to determine the effects of various concentrations of crude oil under different water levels on the growth and survival of selected marsh plants. The plant species tested were *Scirpus olneyi* E. & G. and *Spartina patens* Link., both extremely important perennial plants in the brackish marshes.

Scirpus olneyi, a sedge, is a valuable wildlife food plant, particularly for muskrats (*Ondatra zibethicus*) and snow geese (*Chen caerulescens*) (O'Neil 1949, St. Amant 1959). *Spartina patens*, a grass, is the dominant plant along the Louisiana coast (Chabreck 1972), provides energy support for aquatic systems, and is important for cattle grazing.

Although the coastal area is important from the ecological and recreational standpoint, it also is important from the economical standpoint. Of major economic importance in the coastal marsh is the petroleum industry, which is one of the largest industries in the state. The annual economic return of the oil industry was estimated by St. Amant (1971) to be ten times the economic return of the fish and wildlife industries. He pointed out, however, that the oil resource is non-renewable whereas the fish and wildlife resource is renewable. Most of Louisiana's oil production is centered in the southern part of the state, and about 25,000 oil and gas wells are located within the coastal region (St. Amant 1971). With several large land-use industries occupying the same area, the chance for conflicts of interest is very great.

---

[1] A contribution of the Louisiana Cooperative Wildlife Research Unit: Louisiana State University, Louisiana Wild Life and Fisheries Commission, U. S. Fish and Wildlife Service, Wildlife Management Institute, and American Petroleum Institute, cooperating.

[2] Present address: U. S. Fish and Wildlife Service, National Coastal Ecosystems Team, Bay St. Louis, MS 39520.

METHODS AND MATERIALS

Test Crude Oils

Two types of crude oils, which were obtained from Humble Oil Company, Grand Isle, Louisiana, were used in this study. The oils were collected from offshore wells and were not exposed to air. One type of oil (labeled W-6) was considered light oil since it had 51.36 percent naphtha, a highly volatile substance (Table 1). The other type of oil (labeled P-4) was considered a heavy oil because it had only 16.56 percent naphtha. Physical and chemical analyses were performed on the test crude oils by the Exxon Company, Baton Rouge, Louisiana (Table 1).

Table 1. Results of physical and chemical analysis performed on the test crude oils by the Exxon Company, Baton Rouge, Louisiana.

	Oil Number	
Property	*W-6 Light Oil*	*P-4 Heavy Oil*
Gravity, API at 60° F	40.7	29.0
Viscosity, SSU at 100° F	33.1	88.3
Viscosity, CS at 130° F	1.72	8.22
Viscosity, SSU at 130° F	32.06	52.9
Asphaltenes	.55%[a]	2.12%
Sulfur	.25%	.32%
Naphtha	51.36%	16.56%
Gas oil, 380-600° F	34.58%	36.22%
Heavy Distillate, 600-700° F	4.27%	15.79%
Residuum, 700-1000° F	8.51%	29.93%

[a] All percentages are of the total weight.

Establishment of Plants

S. olneyi and *S. patens* used in this study were collected from a brackish marsh on the northern shore of Lake Pontchartrain, 3 miles (4.8 kilometers) south of Lacombe, Louisiana.

Clumps of *S. olneyi* and *S. patens* were dug by hand and transported to the greenhouse site at the Ben Hur Experiment Station near Baton Rouge, Louisiana. There they were irrigated and held until planting.

The greenhouse used in this study consisted of a poleshed with open sides, a translucent fiberglass roof, and a concrete floor. Therefore, air temperatures, humidity, and wind velocity would be approximately the same inside of the greenhouse as outside. Clay soil from Ben Hur Experiment Station was used as a growth medium for the plants. Ross (1972) found Ben Hur soil to be a satisfactory growth medium for *S. olneyi*.

A total of 576 five-liter plastic buckets were used for the study. One-half of the plastic buckets were planted with two clumps each of *S. olneyi*, and the remainder were planted with two clumps each *S. patens*. The culms of the *S. olneyi* and *S. patens* were pruned to a height of about 20cm. Holes were cut in the buckets to insure uniform water exchange through the soil. The soil and water were adjusted to 5 parts per thousand (ppt) salinity by adding sodium chloride. The plantings were held with the water level at the soil surface until they became established.

After the plants of *S. olneyi* and *S. patens* were well established, they were transferred to 36 metal water tanks in the Ben Hur greenhouse. The plants were placed at four different water levels. This included three constant water levels of +5, 0 and −5cm, and one fluctuated water level of from +5 to −5cm about the soil surface. Two buckets each *S. olneyi* and *S. patens* were placed at each water level in each tank for a total of 16 buckets per tank.

Buckets were placed on the tanks' bottom for the deepest water level (+5cm), while buckets were placed on 5cm platforms for the 0cm water level, and on 10cm platforms for the −5 water level. The fluctuated group of buckets was raised or lowered daily to simulate tidal action. This was done by placing buckets on the bottom (+5cm) for a period of one day and then placing them on 10cm platforms (−5cm) for the following day. This process was repeated on subsequent days for the duration of the study, thus simulating a complete tidal cycle every two days.

A salinity of 5 ppt was maintained in the metal tanks since *S. olneyi* and *S. patens* grow well at this salinity (Ross 1972, Babcock 1967). Fresh water was added as needed to maintain the proper water level and to replace the water lost through evaporation and transpiration.

Oil Treatment

S. olneyi and *S. patens* were exposed to nine treatments, with four tanks randomly assigned to each treatment. Treatments used were: 10, 20, 40, and 80 ppt by volume for both the heavy and the light oil, plus a control not exposed to oil. The plants were exposed to the treatments for 8.5 months from July 10, 1972 through March 25, 1973.

Methods of Assessment

Monthly observations on the plants were: number of culms, height, and survival. The number of live culms in each bucket was counted. Height of *S. olneyi* plants was measured to the nearest centimeter on the tallest living culm in each bucket. If the culm was dead at the tip, only the living portion was measured. Height of the *S. patens* was measured to the nearest centimeter on the tallest living culm and leaf with the leaf held in a vertical position. If the leaf was dead at the tip, only the living portion was measured. Survival was scored as 100 percent if both clumps in the bucket were living, as 50 percent if one clump was living, and as 0 percent if neither clump was living.

An analysis of variance for the number of culms, height, and survival was used to detect possible differences among treatments. Dunnett's Test was used to compare the various treatments with the control (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Factors affecting the number of culms, height, and survival of *S. olneyi* and *S. patens* included the type of oil, the concentration of oil, the water level at which the plants were grown, and the time after initial exposure. These factors did not always affect *S. olneyi* and *S. patens* in the same manner.

Effects of Oil on S. olneyi

Number of Culms

Numbers of culms of *S. olneyi* were not significantly different from the control for any of the oil treatments and water levels during the first two months of exposure to crude oil (Table 2). During subsequent months, the number of culms increased for the various oil treatments at the +5cm water level. By the end of 8.5 months of exposure at the +5cm water level, the number of culms was significantly ($P < 0.01$) greater for all treatments except for the light oil treatment at 10 ppt.

Significantly greater numbers of culms were also present at the fluctuated water level for some treatments by the end of the study. These included the light oil treatments at 20 ppt ($P < 0.05$), 40 ppt ($P < 0.05$), 80 ppt ($P < 0.01$), and the heavy oil treatments at 10 ppt ($P < 0.05$).

There were no significant differences in the number of culms at any treatment at the −5cm and 0cm water levels.

Height Growth

At the end of the 8.5 months of exposure to crude oil, *S. olneyi* had a significantly ($P < 0.01$) greater height at the +5cm water level for light oil at 80 ppt and heavy oil at 40 and 80 ppt. Also, a significantly ($P < 0.01$) greater height was recorded at light oil at 20 ppt at 0cm water level (Table 3).

Height of the *S. olneyi* was significantly ($P < 0.01$) reduced in the heavy oil treatment at 80 ppt at the fluctuated water level. This reduction in height was evident from the third month of treatment through the termination of the study.

A significant ($P < 0.01$) reduction in height was also evident in the heavy oil treatment at 40 ppt at the fluctuated water level from the fourth through the sixth month of treatment. However, by the end of the study period, this treatment did not differ significantly from the control. This suggests that effects of the oil are dependent upon the time after exposure, and that the plants were recovering from this treatment.

Survival

Survival of *S. olneyi* was 100 percent at the +5cm water level for all of the treatments even though oil came in direct contact with the culms (Table 4).

A significant ($P < 0.01$) reduction in plant survival was evident in the heavy oil treatment at 80 ppt at the fluctuated water level, and at the 0cm water level for light oil at 40 ppt, 80 ppt, and for heavy oil at 40 ppt and 80 ppt. For these treatments, survival was reduced to 31.3%, 50.0%, 68.8%, 56.3%, and 56.3% respectively by the end of the study. In comparison, survival for the control at the fluctuated water level and 0cm water level was 93.8% and 87.5% respectively.

Table 2. Mean number of culms of S. *olneyi* after exposure to nine oil treatments.

Treatment	Water Level (cm)	Month								
		July	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*
		Number of culms								
	−5[a]	25.6	28.1	31.3	31.8	24.8	13.8	9.1	5.4	9.5
Light Oil	0	26.4	27.8	28.3	28.3	20.5	10.6	7.0	5.4	8.8
10 ppt	+5	28.5	34.3	41.6	43.3	42.4	23.8	19.8	17.4	29.8
	±5	28.6	36.0	42.0[b]	44.9[c]	41.8[c]	24.0	19.0	15.5	21.1
	−5	22.1	25.0	28.5	26.3	23.3	10.3	5.6	3.9	8.8
Light Oil	0	20.4	23.6	29.4	27.9	25.4	13.8	10.1	6.4	10.8
20 ppt	+5	25.5	35.3	42.1	48.5[c]	50.5[c]	29.0	23.8	22.0	40.6[c]
	±5	18.8	28.4	32.0	33.3	38.0	23.8	20.6	20.0	28.5[b]
	−5	27.9	28.0	29.5	25.9	21.4	9.5	6.0	4.3	6.8
Light Oil	0	24.5	27.5	28.0	24.4	19.6	9.0	4.8	3.0	6.0
40 ppt	+5	24.1	31.9	45.0	47.1[c]	48.6[c]	26.3	22.5	24.8	48.3[c]
	±5	27.1	28.3	37.8	38.9	36.1	23.5	16.9	18.1	29.9[b]
	−5	27.9	28.9	30.0	26.8	19.6	9.9	5.7	3.7	5.2
Light Oil	0	23.9	25.0	25.0	22.5	19.4	11.3	8.8	6.4	9.9
80 ppt	±5	28.3	29.6	43.9	52.3[c]	56.6[c]	34.3	31.8[b]	38.6[c]	59.1[c]
	±5	27.8	31.5	37.3	39.3	39.1[b]	23.5	20.8	21.4	34.1[c]
	−5	17.8	21.4	22.8	20.8	18.1	10.5	4.3	2.0	6.8
Heavy Oil	0	21.5	22.4	23.9	23.8	18.9	10.9	7.6	6.0	10.4
10 ppt	+5	26.6	34.0	41.4	44.0	43.9[b]	29.1	25.0	23.8	40.5[c]
	±5	24.8	28.9	33.9	34.5	34.5	20.3	16.9	16.4	28.5[b]
	−5	25.8	29.3	27.0	24.8	20.1	14.3	6.7	3.4	3.4
Heavy Oil	0	28.3	29.5	29.6	25.3	20.1	12.4	6.4	3.5	8.3
20 ppt	+5	30.1	37.4	46.9	51.0[c]	50.6[c]	26.1	20.6	23.8	47.0[c]
	±5	25.5	30.5	35.4	36.8	34.1	20.3	15.8	17.1	27.5
	−5	22.8	26.3	28.8	25.3	20.9	9.5	6.2	3.2	3.6
Heavy Oil	0	24.4	25.9	26.9	24.0	18.0	10.4	8.6	5.0	8.7
40 ppt	+5	26.4	36.3	48.9[c]	57.1[c]	62.1[c]	36.8[c]	32.4[b]	41.4[c]	60.3[c]
	±5	23.6	24.4	25.9	23.6	21.5	15.1	15.1	19.6	26.8
	−5	22.6	25.8	27.0	23.5	18.3	10.1	6.3	4.1	9.1
Heavy Oil	0	25.3	25.0	25.0	24.4	19.5	10.8	8.4	9.4	15.2
80 ppt	+5	27.1	30.3	36.8	43.5	45.6[b]	35.3[b]	34.3[c]	43.0[c]	57.9[c]
	±5	23.6	20.8	18.8	20.4[b]	17.4[b]	15.9	12.1	10.5	17.0
	−5	23.6	25.1	25.9	23.3	21.8	12.6	8.3	6.0	10.2
Control	0	26.4	26.4	27.9	25.5	22.5	13.3	9.0	5.6	5.8
0 ppt	+5	28.4	31.5	36.2	35.3	34.0	24.5	21.9	19.9	28.3
	±5	22.6	27.8	32.0	31.8	28.0	19.5	16.9	12.4	17.9

[a] Water levels about the soil surface.

[b] Significantly different from the number of culms in the control ($P < 0.05$).

[c] Significantly different from the number of culms in the control ($P < 0.01$).

Table 3. Mean height of *S. olneyi* after exposure to nine oil treatments.

Treatment	Water Level (cm)	Month: July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
		Height in centimeters								
	−5[a]	108.1	105.6	99.8	87.4	76.9	54.9	36.5	30.5	45.1
Light Oil	0	106.0	102.6	96.9	84.9	75.9	49.8	31.6	26.6	35.1
10 ppt	+5	111.1	109.5	105.3	105.3	101.8	92.6	62.6	47.4	74.3
	±5	111.6	107.5	102.9	95.1	91.1	80.3	65.0	53.8	56.9
	−5	109.9	104.3	97.3	85.3	74.1	43.8[b]	26.4[c]	24.06[b]	44.5
Light Oil	0	109.8	103.6	95.9	86.8	77.1	60.3	40.3	30.0	51.6[c]
20 ppt	+5	102.9	100.3	97.9	93.8[c]	89.9[c]	70.9[c]	56.5[c]	43.0[b]	79.5
	±5	108.3	98.4	97.9	91.9	88.8	75.8[c]	57.3[b]	46.8	62.5
	−5	109.8	101.3	95.4	85.8	82.4	55.5	31.8	28.8	35.7
Light Oil	0	108.3	106.0	94.1	82.4	73.4	45.6	26.8	30.2	38.6
40 ppt	+5	109.6	104.6	118.0[c]	114.1	113.2	93.4	68.3	44.1[b]	74.6
	±5	105.5	101.5	100.1	92.6	89.6	83.9	72.3	50.9	64.0
	−5	108.6	106.1	97.4	90.1	78.4	45.3[c]	31.1[b]	26.7	31.8
Light Oil	0	110.4	106.1	97.5	85.5	80.0	56.8	36.9	32.0	35.5
80 ppt	+5	112.1	104.1	111.1	121.6	121.4[b]	103.6[c]	79.1	59.8	88.8[c]
	±5	106.6	103.1	98.9	102.3	92.8	80.5	63.5	52.9	63.1
	−5	110.8	106.1	94.6	86.9	79.0	50.8	26.1[c]	21.5[c]	47.2
Heavy Oil	0	108.8	105.0	100.8	88.1	83.1	58.5	38.6	31.9	45.3
10 ppt	+5	104.5	102.3	100.9	97.1[b]	85.8[c]	74.4[c]	55.3[c]	43.8[b]	77.1
	±5	104.0	101.8	100.4	96.8	89.6	77.3	65.8	55.3	65.1
	−5	109.0	104.7	98.9	92.0	81.5	58.2	35.9	29.9	27.1
Heavy Oil	0	107.6	105.1	101.4	91.8	83.3	61.0	36.4	29.1	34.9
20 ppt	+5	106.8	107.1	108.9	104.6	100.4	79.0	54.9[c]	42.6[b]	77.1
	±5	110.1	106.9	103.4	97.8	89.5	74.0[c]	59.5	50.8	62.3
	−5	111.6	105.0	96.0	83.6	77.8	56.9	31.7	23.8[b]	22.1[c]
Heavy Oil	0	112.8	108.3	96.1	86.9	78.1	61.1	40.0	30.4	34.8
40 ppt	+5	115.8[b]	111.1	116.1[b]	121.1[b]	118.4[b]	103.8	76.6	56.6	91.5[c]
	±5	106.6	103.0	92.5	81.8[c]	75.8[c]	64.4[c]	59.6	55.1	66.8
	−5	113.9	111.6	98.4	88.3	83.1	50.4	32.1	29.0	49.0
Heavy Oil	0	112.8	103.5	91.9	81.6	73.4	49.0	34.3	32.6	40.4
80 ppt	+5	112.8	109.1	104.9	105.8	101.6	89.1	71.9	56.5	96.4[c]
	±5	111.1	101.6	84.3[c]	45.3[c]	31.8[c]	31.1[c]	27.1[c]	30.3[c]	33.0[c]
	−5	105.4	102.3	94.4	85.9	79.4	59.5	43.4	36.6	36.7
Control	0	107.1	104.4	94.8	87.8	78.5	55.8	38.1	33.6	35.3
0 ppt	+5	103.0	103.1	103.8	109.0	105.6	95.6	72.3	56.6	68.3
	±5	102.3	99.5	99.1	96.3	94.0	90.1	69.4	55.5	57.8

[a] Water levels about the soil surface.

[b] Significantly different from the height in the control ($P < 0.05$).

[c] Significantly different from the height in the control ($P < 0.01$).

Table 4. Mean percent survival of *S. olneyi* after exposure to nine oil treatments.

Treatment	Water Level (cm)	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
		Percent								
	−5[a]	100.0	100.0	100.0	100.0	100.0	100.0	87.5	75.0	93.8
Light Oil	0	100.0	100.0	100.0	100.0	100.0	93.8	87.5	75.0	81.3
10 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	81.3	68.8	100.0
Light Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	81.3	87.5
20 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	68.8	62.5
Light Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	56.3	43.8[b]	50.0[b]
40 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	81.3	68.8	43.8[b]
Light Oil	0	100.0	100.0	100.0	100.0	100.0	93.8	100.0	68.8	68.8[b]
80 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	68.8[b]	43.8[b]	56.3
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	87.5	68.8	81.3
10 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	93.8	62.5[b]	68.8	56.3
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	93.8	87.5	87.5
20 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	75.0	56.3[b]	62.5
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	87.5	87.5	62.5	56.3[b]
40 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	93.8	87.5	87.5	100.0	93.8
	−5	100.0	100.0	100.0	100.0	100.0	87.5	87.5	75.0	81.3
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	93.8	68.8	56.3[b]	56.3[b]
80 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	93.8	81.3[b]	81.3[b]	62.5[b]	43.8[b]	31.3[b]
	−5	100.0	100.0	100.0	100.0	100.0	100.0	87.5	75.0	68.8
Control	0	100.0	100.0	100.0	100.0	100.0	100.0	87.5	75.0	87.5
0 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	93.8	93.8	93.8

[a] Water levels about the soil surface.

[b] Significantly different from the survival in the control ($P < 0.01$).

Number of Culms

A reduction in the number of culms of S. *patens* at certain water levels was evident for all oil treatments after two months of exposure (Table 5). Once the reduction occurred, it was evident through the termination of the study, and recovery was not evident. As the study progressed, the number of culms was reduced at additional water levels for most treatments.

Table 5. Mean number of culms of S. *patens* after exposure to nine oil treatments.

Treatment	*Water Level (cm)*	*Month*								
		July	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*
		Number of culms								
Light Oil 10 ppt	−5[a]	27.1	34.3	37.0	43.9	49.8	50.8	48.8	62.6	68.4
	0	26.9	38.0	42.4	50.0	56.4	57.4	58.4	70.8	75.1
	+5	20.6	22.9	28.9	35.1	42.1	46.0	50.0	59.5	67.0
	±5	24.3	25.6	20.6[b]	32.0[c]	32.3[b]	32.0[b]	39.1[b]	42.0[b]	45.4[b]
Light Oil 20 ppt	−5	29.3	33.8	41.8	43.8	47.4	48.4	51.1	56.6	61.9
	0	38.1	47.5[b]	48.9	49.3	66.3	68.4[c]	73.6[b]	80.5	89.9[b]
	+5	19.6	19.4	23.3[b]	22.5[b]	26.9[b]	29.9[b]	33.9[b]	39.4[b]	47.3[b]
	±5	25.4	35.5	29.4	25.5[b]	31.4[b]	27.3[b]	30.0[b]	32.9[b]	35.0[b]
Light Oil 40 ppt	−5	34.8	36.3	41.5	43.3	48.9	51.9	50.6	59.0	68.1
	0	32.1	28.3	29.9[b]	32.9[b]	39.9[b]	40.6[b]	41.4[b]	52.1[b]	54.6[b]
	+5	22.9	24.0	24.1[b]	22.8[b]	28.6[b]	32.1[b]	31.9[b]	37.0[b]	43.0[b]
	±5	32.1	29.0	27.5[c]	28.1[b]	24.9[b]	28.1[b]	18.8[b]	26.5[b]	30.3[b]
Light Oil 80 ppt	−5	27.1	30.1	32.5	37.0	36.5[b]	37.6[b]	37.9[b]	41.4[b]	45.0[b]
	0	24.3	30.8	36.5	41.0	32.8[b]	45.0[b]	47.5[b]	53.8[b]	57.9[b]
	+5	23.4	19.6	19.8[b]	21.3[b]	12.3[b]	18.3[b]	13.4[b]	15.9[b]	15.1[b]
	±5	29.1	20.6	17.5[b]	15.6[b]	8.5[b]	6.8[b]	4.9[b]	4.3[b]	4.2[b]
Heavy Oil 10 ppt	−5	33.0	41.0	43.0	48.5	54.0	53.0	56.8	64.6	70.9
	0	29.6	34.5	39.4	43.0	51.6	52.0	57.3	63.6	68.9
	+5	32.6	30.5	33.8	44.4	40.5	39.5[c]	43.0[b]	49.0[c]	52.3[c]
	±5	32.5	28.0	27.4[c]	26.1[b]	28.9[b]	24.8[b]	24.1	32.3[b]	29.0[b]
Heavy Oil 20 ppt	−5	35.6	38.8	38.8	41.9	43.8	43.9	46.3	55.0	57.4
	0	36.3	42.1	44.1	47.0	50.8	50.4	53.4	58.5	65.5
	+5	25.1	21.1	20.3[b]	20.8[b]	19.3[b]	19.1[b]	17.8[b]	22.7[b]	20.8[b]
	±5	28.6	25.3	22.8[b]	21.5[b]	15.9[b]	16.3[b]	15.05[b]	15.1[b]	15.6[b]
Heavy Oil 40 ppt	−5	30.0	32.6	33.8	39.6	40.5[b]	37.0[b]	38.0[b]	45.4[b]	49.1[b]
	0	26.9	30.8	32.5	32.5[b]	38.1[b]	38.5[b]	41.3[b]	43.5[b]	44.0[b]
	+5	25.5	22.5	22.6[b]	23.3[b]	19.1[b]	20.6[b]	18.4[b]	20.4[b]	20.1[b]
	±5	36.6	28.6	24.9[b]	24.5[b]	17.5[b]	15.8[b]	15.4[b]	11.4[b]	11.3[b]
Heavy Oil 80 ppt	−5	29.4	35.0	39.1	42.6	46.1	46.4	50.3	54.1	59.5
	0	34.9	41.4	42.4	35.1[c]	47.8[c]	46.6[c]	46.3[b]	53.0[b]	55.4[b]
	+5	23.6	20.8	18.8[b]	20.4[b]	17.4[b]	15.9[b]	12.1[b]	10.5[b]	17.0[b]
	±5	26.5	23.5	18.1[b]	23.4[b]	8.0[b]	6.3[b]	6.4[b]	5.8[b]	4.5[b]
Control 0 ppt	−5	32.9	35.0	41.6	45.5	52.3	51.3	54.6	60.3	62.5
	0	31.0	35.1	40.9	46.1	58.3	57.4	60.6	71.9	73.3
	+5	23.5	28.1	35.9	39.8	47.1	50.4	54.9	59.1	63.4
	±5	29.5	29.8	38.3	42.5	51.3	50.1	51.6	59.3	62.4

[a] Water levels about the soil surface.

[b] Significantly different from the number of culms in the control ($P < 0.01$).

[c] Significantly different from the number of culms in the control ($P < 0.05$).

Generally, as the oil concentrations increased, the number of culms decreased. Reduction of numbers of culms was greater for the heavy oil than for the light oil of equal concentrations.

The effect of oil on the number of culms differed for the four water levels. Greatest reduction in the number of culms was at the fluctuated level. This was followed by the +5cm, 0cm and −5cm water levels respectively.

By the end of the 8.5 months of exposure, reduction of the number of culms was evident for a number of treatments and water levels. There was a significant ($P < 0.01$) reduction in the number of culms for all oil treatments at the fluctuated water level. A significant ($P < 0.01$) reduction in the number of culms was present at the +5cm water level for the light and the heavy oil treatments at 20 ppt, 40 ppt, and 80 ppt. The reduction was also significant ($P < 0.05$) at the +5cm water level for the heavy oil treatment at 10 ppt. The number of culms was reduced significantly ($P < 0.01$) at the 0cm water level for the light oil treatments at 20 ppt, 40 ppt, and 80 ppt, and for the heavy oil treatment at 40 ppt and 80 ppt. Reductions in the number of culms were significant ($P < 0.01$) at the −5cm water level for the light oil treatment at 80 ppt and the heavy oil treatment at 40 ppt.

A significant ($P < 0.01$) increase in the number of culms was recorded only at the 0cm water level for the light oil treatment at 20 ppt.

The reduction of culms at the fluctuated water level and at the +5cm water level may have been caused by oil contact with the culm. Cowell (1969) observed that *Spartina townsendii* was adversely affected by crude oil and suggested that the oxygen transport system from the culms to the roots was interrupted by the oil. Such may have been the case with *S. patens* in this study since dissolved oxygen levels of the water were reduced after oil treatment (Gebhart 1973, Gebhart and Chabeck 1973).

The different response of *S. patens* to oil contact from that observed in *S. olneyi* may be due to the different oxygen transport systems of these plants. Laing (1940) reported that in flooded soils oxygen was transported in *Scirpus validus* by way of the culms to the roots. If *S. olneyi* functioned in the same manner, the oil reducing the dissolved oxygen in the water would not be a limiting factor in its growth.

Height Growth

Height of *S. patens* was reduced at the fluctuated, +5cm, and 0cm water levels at the higher oil concentrations (Table 6). At these water levels, heavy oil reduced the height of *S. patens* more than did light oil of equal concentrations.

At the end of the study period, reduction in height was significant ($P < 0.01$) at the fluctuated and +5cm water levels for both light and heavy oil treatments at 80 ppt. Significant ($P < 0.05$) reductions in height were also present at the fluctuated water level for the heavy oil treatment at 40 ppt, and at the 0cm water level for the heavy oil treatment at 80 ppt.

Survival

Survival of *S. patens* was high for most treatments (Table 7). A significant ($P < 0.01$) reduction in survival was evident only at the fluctuated water level for the light oil treatment at 80 ppt, and for the heavy oil treatments at 20, 40, and 80 ppt. Here survival dropped to 50.0%, 81.3%, 75.0%, and 43.8% respectively by the end of the study. In comparison, survival for the control was 100%.

Where a reduced survival was evident, there was lower survival for the heavy oil treatments than for the light oil treatments of equal concentrations. Among the heavy oil treatments, survival decreased as the oil concentrations increased.

Table 6. Mean height of *S. patens* after exposure to nine oil treatments.

Treatment	Water Level (cm)	Month								
		July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
		Height in centimeters								
	−5[a]	91.0	96.6	98.6	95.5	92.9	88.9	86.0	82.4	85.1
Light Oil	0	93.1	105.8	108.4	105.0	103.4	100.0	94.9	93.3	94.0
10 ppt	+5	84.8	97.0	111.1	111.3	112.3	106.5	105.8	98.5	102.1
	±5	97.0	95.8	97.3	97.9	90.5	89.3	86.8	86.5	88.9
	−5	95.3	100.3	100.6	96.0	90.8	88.8	86.8	86.1	83.8
Light Oil	0	101.4	105.1	106.1	104.0	103.9	98.9	97.9	95.1	94.6
20 ppt	+5	93.4	106.4	109.5	111.4	106.4	105.0	102.9	97.3	103.3
	±5	94.6	97.4	99.6	98.5	91.5	87.0	87.6	74.4[b]	85.9
	−5	95.6	104.3	106.1	103.4	99.0	96.1	91.6	88.9	87.6
Light Oil	0	102.8	108.5	109.4	103.4	103.5	95.4	91.8	91.4	89.6
40 ppt	+5	92.4	98.3	103.0	98.9	96.6	92.6	86.0	72.1[c]	88.9
	±5	105.0	102.3	104.3	98.8	87.3	85.3	84.4	80.8	92.6
	−5	93.8	92.6	92.1	91.0	87.1	83.0	79.6[b]	74.3[c]	79.0
Light Oil	0	99.9	105.6	105.8	102.8	102.0	96.1	92.8	90.8	93.8
80 ppt	+5	97.1	99.1	95.0	95.6[c]	85.5[c]	81.1[c]	76.0[c]	69.5[c]	72.6[c]
	±5	97.4	96.1	98.9	91.0	73.0[c]	64.3[c]	52.6[c]	47.9[c]	60.6[c]
	−5	90.1	97.3	97.3	95.1	93.5	89.6	85.9	84.4	82.8
Heavy Oil	0	96.1	103.6	105.4	105.0	101.4	97.6	94.4	93.5	95.9
10 ppt	+5	94.9	109.5	108.0	109.3	105.4	102.0	97.4	99.6	103.1
	±5	97.0	91.0	96.5	94.3	91.9	90.6	80.1	87.9	81.9
	−5	98.5	101.8	103.6	103.4	98.4	95.1	90.3	83.0	84.3
Heavy Oil	0	104.0[b]	110.9	110.4	106.4	101.3	96.8	93.8	89.6	91.9
20 ppt	+5	94.4	102.8	99.3[b]	89.4[c]	93.6	90.3	86.5	81.6	85.6
	±5	98.8	102.5	100.0	97.4	88.0	82.0	86.3	81.3	92.9
	−5	95.8	101.3	103.3	105.4	100.3	96.1	89.0	88.4	84.9
Heavy Oil	0	95.1	101.8	107.1	102.0	97.9	92.4	92.9	87.4	93.6
40 ppt	+5	89.4	99.8	98.9[c]	99.3[c]	93.3	90.1	94.1	77.8[c]	85.3
	±5	92.1	93.6	90.3	83.9[b]	76.1[c]	74.9[c]	71.8[c]	65.1[c]	74.0[b]
	−5	95.0	105.4	101.6	100.6	95.0	90.5	87.0	84.0	86.8
Heavy Oil	0	89.5	98.5	95.6[b]	95.1[b]	87.6[b]	83.3[c]	80.4[c]	77.8[c]	80.0[b]
80 ppt	+5	92.0	97.3	97.4[c]	96.1[c]	89.9[b]	86.6[b]	79.0[c]	68.5[c]	69.6[c]
	±5	97.1	100.1	98.5	96.9	85.1[b]	70.0[c]	82.0	76.0	67.7[c]
	−5	96.1	101.4	101.9	98.6	96.0	93.0	93.6	88.6	88.8
Control	0	91.9	102.5	108.3	107.4	104.3	101.0	98.1	94.8	92.3
0 ppt	+5	92.0	106.0	113.1	113.8	103.6	100.3	95.5	93.0	92.9
	±5	94.8	101.3	103.0	97.3	97.9	92.8	91.5	87.8	86.8

[a] Water levels about the soil surface.

[b] Significantly different from the height in the control ($P < 0.05$).

[c] Significantly different from the height in the control ($P < 0.01$).

Table 7. Mean percent survival of *S. patens* after exposure to nine oil treatments.

Treatment	Water Level (cm)	Month								
		July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
		Percent								
	−5[a]	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Light Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Light Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	93.8	93.8	93.8	93.8	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Light Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
40 ppt	+5	100.0	100.0	100.0	87.5	93.8	93.8	93.8	93.8	87.5
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Light Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
80 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	93.8	100.0	100.0
	±5	100.0	100.0	100.0	100.0	93.4	87.5	81.3[b]	75.0[b]	50.0[b]
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	93.8	100.0	100.0	87.5	81.3[b]	87.5
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20 ppt	+5	100.0	100.0	100.0	100.0	93.8	93.8	87.5	87.5	100.0
	±5	100.0	100.0	100.0	100.0	93.8	93.8	87.5	87.5	81.3[b]
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
40 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	87.5	87.5	100.0	81.3[b]	75.0[b]
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Heavy Oil	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
80 ppt	+5	100.0	100.0	100.0	100.0	93.8	93.8	93.8	93.8	87.5
	±5	100.0	100.0	100.0	100.0	81.3[b]	68.8[b]	56.3[b]	62.5[b]	43.8[b]
	−5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Control	0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
0 ppt	+5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	±5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Water levels about the soil surface.

[b] Significantly different from the survival in the control ($P < 0.01$).

LITERATURE CITED

Babcock, K. M. 1967. The influence of water depth and salinity on wiregrass and saltmarsh grass. Unpubl. Master's Thesis. La. St. Univ. 109 p.

Baker, J. M. 1971. Seasonal effects of oil pollution on salt marsh vegetation. Oikos 22:106-110.

Chabreck, R. H. 1972. Vegetation, water and soil characteristics of the Louisiana coastal region. La. Agric. Exp. Sta. Bull. 664. 62 p.

Chabreck, R. H. 1973. Bird usage of marsh ponds subjected to oil spills. Proc. La. Acad. of Sci. 36:101-110.

Cowell, E. B. 1969. The effect of oil pollution on saltmarsh communities in Pembrokeshire and Cornwall. J. Appl. Ecol. 6:133-142.

Cowell, E. B. 1971. Some effects of oil pollution in Milford Haven, United Kingdom. p. 429-436. *In* L. P. Haxby (ed.) Prevention and control of oil spills. Proc. of Symposium, Am. Petr. Inst., Wash., D. C.

Gebhart, J. L. 1973. The effects of varying levels of crude oil on plants of the Louisiana coastal marshes. Unpubl. Master's Thesis. La. St. Univ. 77 p.

Gebhart, J. L. and R. H. Chabreck. 1973. The effects of crude oil on dissolved oxygen levels. Proc. 27th Annu. Conf. of the Southeast. Assoc. of Game and Fish Comm. p. 336-338.

Laing, H. E. 1940. The composition of the internal atmosphere of *Nuphar advenum* and other water plants. Am. J. Botany 27:861-868.

O'Neil, T. 1949. The muskrat in the Louisiana coastal marsh. La. Wild Life and Fisheries Comm., New Orleans. 159 p.

Ross, W. M. 1972. Methods of establishing natural and artificial stands of *Scirpus olneyi*. Unpubl. Master's Thesis. La. St. Univ. 100 p.

St. Amant, L. S. 1959. Louisiana wildlife inventory and management plan. La. Wild Life and Fisheries Comm., New Orleans. 329 p.

St. Amant, L. S. 1971. Impacts of oil on the Gulf Coast. Trans. N. Am. Wildl. and Nat. Res. Conf. 36:206-218.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics, with special reference to the biological sciences. McGraw-Hill Book Co., Inc., New York. 481 p.