organisms (Gunter, 1967). Brackish water ponds connected with tidal channels are also widely used by marine organisms. Many species used the saline and brackish ponds and lakes as nursery areas. The adults spawn offshore and the young move to the inland waters as a part of their life cycle. Rapid growth and development taken place in the rich waters of these areas.

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LITERATURE CITED

Barrett, Barney. 1970. Water measurements of Coastal Louisiana. La. Wildlife and Fisheries Comm., New Orleans. 196 p.

Canfield, R. H. 1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Chabreck, Robert H. 1970a. Marsh zones and vegetative types in the Louisiana Coastal Marshes. Unpubl. Ph.D. Dissertation, La. State Univ. 113 p.

———. 1970b. Vegetation and size of hydrologic units along the Louisiana coast. La. Coop. Wildlife Research Unit, L.S.U., Baton Rouge, Typewritten report. 34 p.

Chabreck, Robert H. and Ted Joanen and A. W. Palmisano. 1968. Vegetative type map of the Louisiana Coastal Marshes. La. Wildlife and Fisheries Comm., New Orleans.

Gunter, Gordon. 1967. Some relationships of estuaries to the fisheries of the Gulf of Mexico, p. 621-639. *In* G. H. Lauff (Ed.), Estuaries. The Horn-Shafer Co., Baltimore.

Kniffen, F. B. 1968. Louisiana, its land and people. La. State Univ. Press. Baton Rouge. 196 p. illus.

Martin, A. C. and F. M. Uhler. 1951. Food of game ducks in the United States and Canada. U. S. Fish and Wildlife Service. Research Report 30. 308 p.

Penfound, W. T. and E. S. Hathaway. 1938. Plant communities in the marshland of southeastern Louisiana. Ecol. Monogr. 8:1-56.

THE EFFECT OF SALINITY ON THE GERMINATION AND GROWTH OF PLANTS IMPORTANT TO WILDLIFE IN THE GULF COAST MARSHES

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INTRODUCTION

Salinity, as a factor affecting plant growth, is frequently encountered in two types of environments. In arid climates, where evapotranspiration exceeds precipitation, salts may accumulate in soils and water to toxic levels. The coastal environment is also subject to high salinities as a result of inundation by sea water. Louisiana alone has more than 4,000,000 acres of coastal marshland, 65 percent of which contains sufficient soluble salts, in the soil water, to affect plant growth and distribution (Chabreck, Joanen and Palmisano, 1968; O'Neil, 1949).

Subsidence, erosion and compaction are natural processes allowing the encroachment of sea water into fresh marshes and swamps. This

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trend has been accelerated by man's activities in the coastal marsh. The Mississippi River was leveed and channelized to control flooding and maintain a navigable channel. Fresh water and sediment are presently discharged in deep water near the continental shelf and are no longer deposited in the marshes flanking the river channel. Oil exploration and development has honey-combed the coast with access canals, spoil levees and pipeline crossings. The natural hydrologic patterns of coastal Louisiana have been altered considerably by such projects. As a result, saline marsh has moved inland two to five miles in the past 25 years (Chabreck, 1970; Palmisano, 1970). This distance is more than the total extent of estuarine marsh in most coastal states.

Plant communities are responsive to changes in salinity regimes. Few species can tolerate extreme fluctuations in salt content of ground water. Thousands of acres of saline marsh are often dominated by a relatively few species of emergent plants. Marshes of intermediate salinity (3 to 15 ppt) are composed of numerous species some endemic to this zone and others which are dominant species in saline and fresh marshes, but also occur in the brackish zone (Penfound and Hathaway, 1938; Chabreck, 1970; Palmisano, 1970).

Diversity is an important factor responsible for the value of coastal Louisiana as wildlife and fishery habitat. Over 6 million ducks and geese, one-fourth the total North American waterfowl population, winter in these marshes annually (Martinson, Voelzer and Meller, 1969). Fresh and brackish marsh winter approximately 90 percent of these birds. Louisiana's coastal marshes are also the leading fur producing habitat in the nation. Over $7,000,000 worth of furs were taken during the 1968-1969 trapping season. Approximately 1,800,000 nutria were trapped, 99.8 percent of the national catch for this species (O'Neil, 1970). Muskrats totaled 1,557,000 pelts, over one-fourth the national catch. Louisiana's seafood industry has a wholesale processed value of approximately $60 million dollars (Ford, 1968). Shrimp, oysters, crabs, menhaden and other estuarine fishes rely on the brackish and saline marshes for all, or part, of their life cycle. Although salinity is only one factor affecting the productivity of coastal environments, it is an important index used in their evaluation and management.

This study was undertaken to determine the effects of salinity on the germination and growth of coastal marsh plants and to determine soluble salt concentration required for optimum growth.

STUDY PROCEDURES

Germination. Seeds used in germination experiments were collected in the vicinity of Rockefeller Wildlife Refuge in Cameron Parish, Louisiana. The seeds were cleaned of chaff with an Erickson seed blower and stored under refrigeration in sealed polyethylene bags. All germination studies were conducted in a Stults germinator. Conditions in the germinator alternated between 14 hours of light at 35°C (95°F) and 10 hours of darkness at 20°C (62°F). Circulating water in the unit produced a relative humidity of 100 per cent. Previous experiments indicated that these were optimum conditions for germination (Palmisano, 1967). All seeds were germinated in petri dishes on two layers of filter paper moistened with 5.0 ml. of appropriate solution.

The effects of five levels of sodium chloride (0, 3, 6, 9, and 12 ppt) on the germination of ten species of marsh plants were tested to determine salinity tolerance. Reagent grade sodium chloride was added to distilled water to give the desired concentration. Three petri dishes containing 50 seeds were tested for each species at each concentration. Results were measured after 27 days in the germinator.

Sand Culture. Several experiments were performed using sand culture techniques and artificially prepared nutrient solutions. A pure grade of silica sand was used in each experiment. The basic nutrient solution was the same as solution no. 2 described by Hoagland and Arnon (1950). A chelated form of iron was used and sulfuric acid was used to adjust the pH to 6.0. Solutions were changed every two weeks.

The experiments were conducted under greenhouse conditions. Temperatures were maintained above 60°F and occasionally reached a maximum of 100°F.

RESULTS AND DISCUSSION

Germination

The term germination, as used in this study, refers only to the obvious emergence of the embryo from the seed. The Association of Official Seed Analysts (1960) defines the term as "the emergence and development from the seed embryo of those essential structures which for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions." Seedlings which developed abnormally were noted.

Salinity and Germination

The effect of salinity on the germination of ten species of marsh plants was examined to determine relative salt tolerances. A preliminary experiment was conducted with pure sodium chloride and an artificially prepared sea salt mixture to determine if there was a difference in germination response. *Scirpus robustus* averaged 95.3 percent and 84.0 percent germination at 6 and 12 ppt sodium chloride. This species averaged 96.0 percent and 84.6 percent germination in artificially prepared sea salt at the same salinity levels. These results indicate no difference in germination response for the two types of salt solutions. *Scirpus olneyi* yielded similar results; therefore, reagent grade sodium chloride was used to test salinity tolerance in future experiments.

Two different response types were detected after subjecting the data to an analysis of regression. Four species showed a negative linear response to increasing salinity, five species showed a significant negative quadratic response, and one species was not significantly affected

TABLE 1. Wildlife utilization of Louisiana coastal marsh plants.

	Food		Cover	
	Waterfowl	Fur Animals	Waterfowl	Fur Animals
Scirpus olneyi [a,b]	high	high	high	high
Scirpus robustus [a,b,c,e]	high	high	high	high
Scirpus americanus [a,b]	high	high	high	high
Echinochloa walteri [b,c,e]	high	moderate	moderate	moderate
Oryza sativa [b,e]	high	low	low	low
Polygonum pennsylvanicum [b,e]	high	low	low	low
Spartina patens [a,b]	moderate	moderate	high	high
Distichlis spicata [a,b,c]	moderate	moderate	moderate	moderate
Sesuvium portulacastrum [d]	high	low	low	low
Setaria magna [c,e]	moderate	moderate	moderate	moderate
Sacciolepis striata [e]	moderate	low	low	low

References:
[a] O'Neil, 1949.
[b] Martin, Zim & Nelson, 1951.
[c] Jemison & Chabreck, 1962.
[d] Chabreck, 1964.
[e] Glasgow & Bardwell, 1962.

by salinity (Table 2). The "Y" intercept (a) indicates the theoretical germination (per 50 seed) at zero salinity. The regression coefficient (b) describes the change in germination with a unit change in salinity. These values can therefore be compared to determine the relative salinity tolerance of each species within a given response type. The smaller the numerical regression coefficient, the less germination is affected by salinity.

Distichlis spicata was the most salt tolerant in the linear response group, although germination, even at 0 ppt, was low. Calculated 50 percent reduction in germination occurred at 7.7 ppt. *Scirpus olneyi* and

Scirpus americanus exhibited very similar salinity responses. Both the regression coefficients and the 50 percent reduction values show *S. olneyi* to be slightly more salt tolerant than *S. americanus*. *Setaria manga* was the least salt tolerant species in the linear response group, using the regression coefficient for comparison. The 50 percent germination reduction point, however, was 6.5 ppt which was greater than for *S. olneyi* and *S. americanus*.

This ranking is consistent with what would be expected based on the ecology of these species. *Distichlis spicata* is found in saline and brackish marshes, *S. olneyi* in the brackish to nearly fresh marshes, *S. americanus* and *Setaria magna* on the fresher sites.

TABLE 2. Effect of salinity on germination (avg. of 3 replications of 50 seeds each).

Species		Coefficient of Determination	50% Germination Reduction (ppt)
	Linear Response Group		
Distichlis spicata	$Y = 8.87 - 0.578X$	.408**	7.7
Scirpus olneyi	$Y = 10.13 - 0.967X$	.610**	5.9
Scirpus americanus	$Y = 11.2 - 1.067X$	.597**	4.7
Setaria magna	$Y = 18.53 - 1.41X$	.892**	6.5
	Quadratic Response Group		
Echinochloa walteri	$Y = 11.06 - .036X^2$	.376*	3.9
Oryza sativa	$Y = 39.27 - .079X^2$	.711**	15.8
Scirpus robustus	$Y = 43.41 - .100X^2$	.934**	14.7
Polygonum pennsylvanicum	$Y = 41.03 - .203X^2$	.934**	10.0
Sacciolepis striata	$Y = 53.03 - .265X^2$	.757**	10.0
	No Response		
Sesuvium portulacastrum	$Y = 45.86 - 0$	.114 N.S.	...

* .05 significance level.
** .01 significance level.

Most species in the quadratic response group exhibited high percentage germination in distilled water. Germination was only slightly reduced at lower salinity levels but dropped sharply at the higher levels. *Echinochloa walteri* had the smallest regression coefficient in this group, indicating it was the most salt tolerant. Fifty percent reduction in germination occurred at only 3.9 ppt but this was a result of the low germination rate in distilled water (11%). Cultivated rice proved to be quite salt tolerant with a low regression coefficient. The salinity level at which a 50 percent reduction in rice germination occurred was 15.8 ppt, the highest for any species tested except *Sesuvium portulacastrum*. *Scirpus robustus* germination response was similar to rice with a regression coefficient of $.100X^2$ and a 50 percent germination reduction level of 14.7 ppt. Pink smartweed exhibited a very uniform curvilinear response to salinity. This species is much less tolerant to salinity than the three preceding species in this group. The regression coefficient was twice that of *S. robustus* and the 50 percent germination reduction level was 10.0 ppt. *Sacciolepis striata* showed little effect of salinity up to 9 ppt; at this point, germination was reduced from 90 percent to 13 percent at 12 ppt. This sharp drop accounted for the high regression coefficient and the 50 percent germination reduction level of 10.0 ppt.

Salinity tolerance within the quadratic group was not consistent with the field ecology of the species. *Echinochloa walteri* and *Oryza sativa* are generally found growing in salinities of less than 10 ppt (Penfound and Hathaway, 1938; Martin, 1957). *Scirpus robustus* however, is a typically brackish or saline marsh plant tolerating salinities over 30 ppt. *Sacciolepis striata* and *Polygonum pennsylvanicum* are fresh marsh plants growing in salinities of less than 5 ppt. *Oryza sativa* and *Echinochloa walteri*, therefore, exhibited an unexpectedly high tolerance to

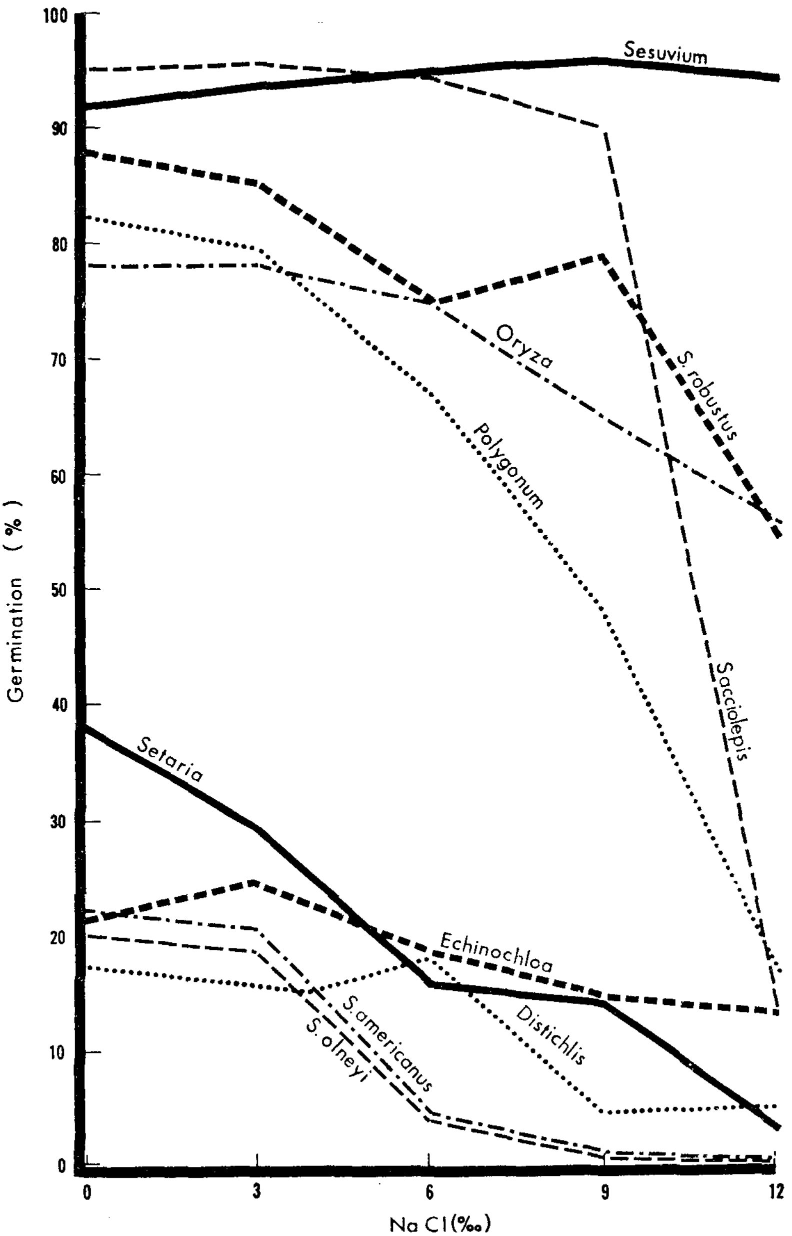

FIGURE 1. The effect of NaCl concentration on the germination of marsh plant seeds

salinity, and the results of germination experiments might be misleading if used to infer relative salinity tolerance under field conditions.

Sesuvium portulacastrum proved to be the most salt tolerant of any species tested. Germination actually increased slightly with increasing salinity. Analyses showed no statistically significant effect of salinity on the germination of this species within the salinity range tested. This species may develop into an important waterfowl food plant in marshes of high salinities. It is presently heavily utilized locally in coastal Louisiana (Chabreck, 1964).

Salinity and Growth

The effects of salinity on the growth of marsh plants were tested in several sand culture experiments. The first experiment involved the growth of *Scirpus olneyi* and *Scirpus robustus* rhizome nodes in 5 gallon crocks irrigated with a nutrient solution and artificially prepared sea water (Clark and Clark, 1964). Plants were harvested and weighed after 62 days growth under greenhouse conditions. Both species exhibited significant growth reduction at increased salinity levels. Table 3 presents the results of an analysis of regression performed on the data collected from the sand culture experiment. *Scirpus olneyi* culm growth was reduced 6.402 grams per unit increase in salinity (1 ppt). A highly significant negative relationship was demonstrated. The predicted growth at zero salinity was 120.58 grams. Roots showed a much slower growth rate than culms and averaged only 17.39 grams at zero salinity. The regression equation for the relationship of root growth and salinity was complex and involved linear, quadratic and cubic responses. This complex equation gave the only statistically significant results. No growth was recorded above 20 ppt salinity and rhizome survival was reduced 50 percent at 16 ppt when compared to the control grown in nutrient solution alone.

TABLE 3. Regression analysis of salinity and growth response of *Scirpus olneyi* and *Scirpus robustus*.

	Regression Equation	Coefficient of Determination
Scirpus olneyi		
culms	$Y = 120.58 - 6.402X$	.251**
roots	$Y = 17.39 - 5.23X + .525X^2 - .014X^3$	.238**
culm - root ratio	$Y = .977 - .0436X$	.776**
Scirpus robustus		
culms	$Y = 16.71 = .133X^2 + .00477X^3$	.360*
roots	$Y = 7.63 - .0083X^2$	.088*
culm - root ratio	$Y = 2.12 - .0156X^2 + .00062X^3$	.766**

* Significant at .05 level.
** Significant at .01 level.

Predicted *Scirpus robustus* culm growth was only 16.71 grams at zero salinity, much less than that for *Scirpus olneyi.* The response curve could best be predicted by an equation involving both quadratic and cubic components. Root growth was also much less than that recorded for *Scirpus olneyi,* 7.63 grams at zero salinity. A significant quadratic response was found, but as shown by the low coefficient of determination, only 8.8 percent of the variation in growth could be accounted for by the effects of salinity. Salinity tolerance was essentially the same for both species. Survival was reduced 50 percent at 17 ppt salinity, and the upper limit of growth was 21 ppt.

A second salinity tolerance experiment yielded similar results (Fig. 2). Growth curves for *Scirpus olneyi* and *Scirpus robustus* were practically identical. Fifty percent growth reduction occurred at 10 ppt NaCl for both species. *Spartina patens* exhibited a much lower growth

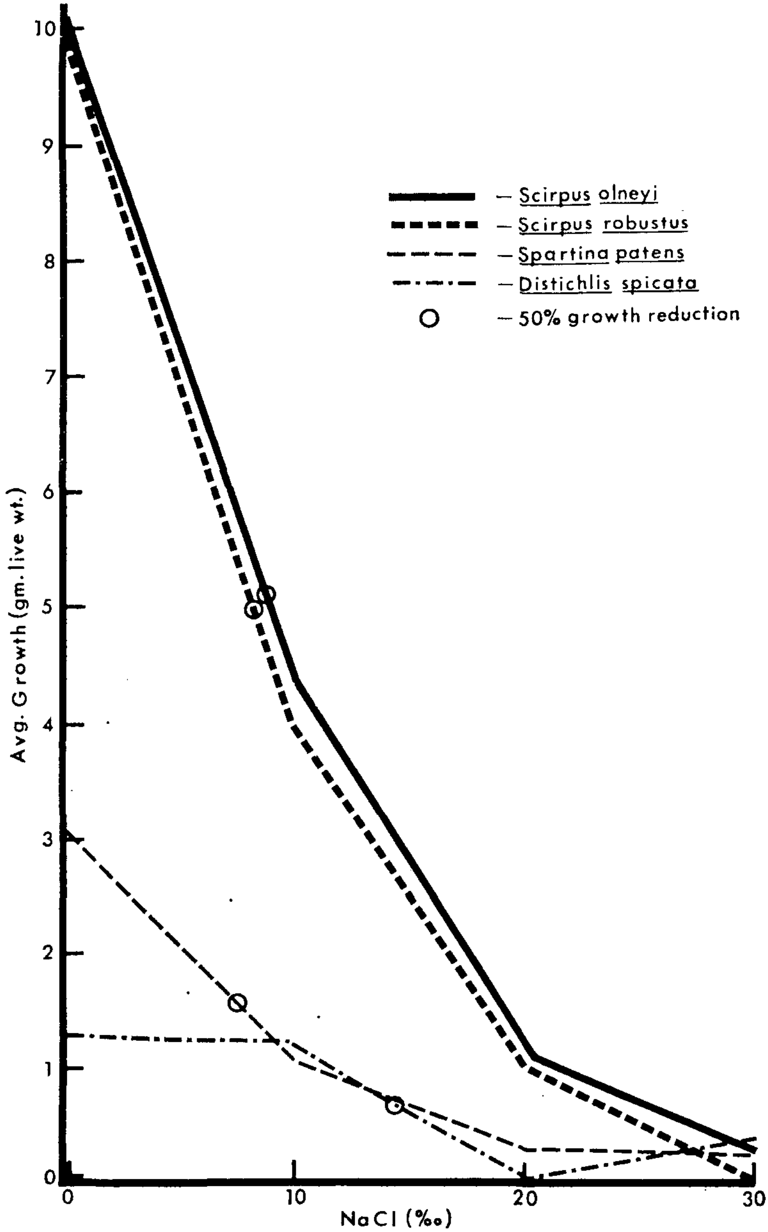

FIGURE 2. The effect of NaCl concentration on the growth of marsh plants

rate at zero salinity level and a rapid decline in growth to 20 ppt NaCl, at which point the curve leveled off. *Distichlis spicata* showed the slowest growth rate but the greatest salinity tolerance. Growth was reduced 50 percent at 15 ppt NaCl.

Bernstein and Hayward (1958) stated that one mechanism plants have for overcoming high osmotic pressures in the growth medimum was a reduction in the shoot/root ratio at higher salinities. This reduced ratio would result in an increased water absorptive area provided by the roots and a decrease in water transpiration area afforded by the culms. This phenomenon would be of some interest to wildlife investigators because rhizomes and roots of perennial grasses and sedges furnish much food for important fur-bearing mammals and waterfowl in the coastal marshes.

Salinity significantly reduced the overall growth rate of all species tested. At higher salinity levels culm growth was more restricted than root growth. The results of the regression analysis presented in Table 3 show a highly significant reduction in the culm-root ratio on both *Scirpus robustus* and *Scirpus olneyi* with increasing salinity. Salinity accounted for approximately 77 percent of the variation in the culm-root ratio as shown by the coefficient of determination. Although overall growth is suppressed, rhizome production is not reduced as drastically as culm growth.

SUMMARY

This study was undertaken to determine the basic ecological factors influencing the distribution of important wildlife food plants in coastal Louisiana. Laboratory experiments were conducted to determine the effects of salinity on seed germination and plant growth. All species examined, except *Sesuvium portulacastrum,* exhibited significant reduction of germination with increasing salinity. Relative response was determined by comparing regression equations for each species. Two different response types were detected, linear and quadratic. *Distichlis spicata, Scirpus olnyi, Scirpus americanus* and *Setaria magna* were in the linear response group. They are listed in decreasing order of salinity tolerance. In the quadratic response group were, *Echinochloa walteri, Oryza sativa, Scirpus robustus, Polygonum pennsylvanicum* and *Sacciolepis striata.* These species are also listed in order of decreasing salinity tolerance. The slope of the regression equation was used to compare the salinity tolerance and the "Y" intercept, the theoretical germination in distilled water.

Growth experiments were carried out under greenhouse conditions using sand culture techniques. Salinity reduced the growth of all species tested. *Scirpus olneyi* and *Scirpus robustus* exhibited high growth rates at low salinity levels but growth was severely restricted at salinities over 20 ppt NaCl. Growth rates of *Distichlis spicata* and *Spartina patens* were slower at low salinities but were less affected by higher levels. Regression equations were used to describe the effect of salinity on plant growth.

LITERATURE CITED

Assoc. of Offic. Seed Analysts. 1960. Rules for testing seeds. Proc. Assoc. Offic. Seed Analysts. Vol. 49. 71pp.

Bernstein, L. and H. E. Hayward. 1958. Physiology of salt tolerance. Annu. Rev. Plant Physio. 9:25-46.

Chabreck, R. H. 1964. Refuge Division Research, p. 195, *In* Biennial Report, 1962-1963. Louisiana Wild Life & Fisheries Comm. New Orleans, Louisiana.

————, 1970. Marsh Zones and Vegetative Type in the Louisiana Coastal Marshes. Ph.D. Dissertation. Louisiana State University. Baton Rouge, Louisiana. 113pp.

Chabreck, R. H., J. T. Joanen and A. W. Palmisano. 1968. Vegetative type map of the Louisiana coastal marshes. La. Wildlife and Fish. Comm. New Orleans, La. 1 p.

Clark, J. R. and R. L. Clark, 1964. Seawater systems for experimental aquariums. Research Report No. 63 U. S. D. I. Fish and Wildlife Service. Washington, D. C.
Ford, T. B. 1968. Oysters, Water Bottoms and Seafoods Division. p. 167. *In* 12th Biennial Report, 1966-1967. Louisiana Wild Life and Fisheries Comm. New Orleans, Louisiana.
Glasgow, L. L. and J. L. Bardwell, 1962. Pintail and teal foods in South Louisiana. Proc. Annu. Conf. S. E. Assoc. of Game and Fish Comm. 16: 175-184.
Hoagland, D. R. and D. I. Arnon. 1950. The water-culture method for growing plants without soil. Cal. Agr. Exp. Stat. Cir. No. 347.
Jameison, E. S. and R. H. Chabreck, 1962. The Availability of Waterfowl Foods in Coastal Marsh Impoundments in Louisiana. Trans. 27th. N. A. Wildl. Conf. 27:288-300.
Martin, H. B. 1957. Louisiana gulf coast marsh handbook. U.S.D.A. Soil Conserv. Serv. Alexandria, Louisiana. Ch. 6:1-17.
Martin, A. C., H. S. Zim and A. L. Nelson, 1951. American Wildlife and Plants, A Guide to Wildlife Food Habits. Dover Publications, Inc., New York. 500pp.
Martinson, R. K., Voelzer, J. F., and Meller, S. L. 1969. Waterfowl Status Report, 1969. Special Scientific Report—Wildlife No. 128. Bureau of Sport Fisheries and Wildlife. Washington, D. C. 153pp.
O'Neil, Ted. 1949. The muskrat in the Louisiana coastal marshes. Pub. Fed. Aid Soc. La. Dept. of Wildlife and Fisheries. 152 pp.
————. 1970. Fur Division, pp. 106-113. *In* 13th Biennial Report, 1968-1969. Louisiana Wildlife and Fisheries Comm. New Orleans, Louisiana.
Palmisano, A. W. 1967. Ecology of *Scirpus olneyi* and *Scirpus robustus* in Louisiana coastal marshes. Unpubl. M. S. Thesis, La. State Univ., Baton Rouge. 145 pp.
————. 1970. Plant Community—Soil Relationships in Louisiana Coastal marshes. Ph.D. Dissertation. Louisiana State Univ. Baton Rouge, Louisiana. 98 pp.
Penfound, W. T. and E. S. Hathaway. 1938. Plant communities in the marshland of southeastern Louisiana. Ecol. Monogr. 8:1-56.

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FOODS OF DUCKS WINTERING IN COASTAL SOUTH CAROLINA, 1965-1967 [1]

By JAMES A. KERWIN [2] and LLOYD G. WEBB [3]

ABSTRACT

During the wintering seasons of 1965-1967, 706 waterfowl gizzards were collected and subsequent food habit studies were made. The collections represented 14 species of waterfowl (9 species of dabblers and 5 species of divers). Six hundred and five collections constituted the dabbling duck sample and 101 gizzards represented the diving duck sample. The most important foods consumed were from fresh and slightly brackish water habitats. Seeds of marsh plants and vegetative fragments and

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[1] A contribution of the South Carolina Wildlife Resources Department, Clemson University Agricultural Experiment Station, and the Bureau of Sport Fisheries and Wildlife.
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