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Some Effects of 30 Years of Weir-Management on Coastal Marsh Aquatic Vegetation and Implications to Waterfowl Management

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Aquatic vegetation was compared between weir-managed and unmanaged brackish marsh ponds at Marsh Island, Louisiana, parts of which have been weir-managed since 1958. Coverage by aquatic vegetation was greater in weir-managed ponds than in unmanaged ponds, but weir-management affected individual species differently. *Eleocharis parvula* was more common in unmanaged ponds than in managed ponds during the early 1960s but has not occurred in any ponds sampled since then. *Ceratophyllum demersum* and the dominant plants *Myriophyllum spicatum* and *Ruppia maritima* were more common in weir-managed ponds than in unmanaged ponds, although the magnitude of the difference varied greatly among sample dates. Because *Myriophyllum spicatum* and *Ruppia maritima* are important and preferred duck foods in Louisiana brackish marsh, it was concluded that weir-management improved habitat quality for migrant and resident ducks at Marsh Island. Weir-managed ponds contained more aquatic vegetation than unmanaged ponds in 1988, even though the crest of weirs had lost 15 cm of elevation relative to rising sea level and the accreting marsh surface. This suggests that aquatic vegetation can be increased with a greater degree of water exchange than previously believed, which is desired to reduce interference to juvenile fish and crustacean movement. Weir-managed and unmanaged ponds did not differ in pond depth, which suggests that weir-management did not affect sedimentation.

Weirs are low level dams constructed from sheet pilings in tidal channels of a marsh. Weirs have been used in Louisiana coastal marshes for over 30 years for waterfowl and fur animal management (Louisiana Wild Life and Fisheries Commission, 1964:163). The crest of a weir is usually constructed 15 cm below the marsh surface; the marsh surface lies about 30 cm above mean water level (Chabreck and Hoffpauir, 1962). Normal tidal range is about 30 cm on the Louisiana coast, thus weirs allow high tide to flood the marsh but interfere little with normal low tide levels. Their purpose is to reduce drainage of tidally influenced ponds during prolonged low water common during winter (Chabreck and Hoffpauir, 1962). Tide-gauge data and pond-bottom contours indicate that during such times, 64% of unmanaged ponds drain but only 14% of weir-managed ponds drain (Chabreck et al., 1979). This has desirable effects. Salinity fluctuates less in managed ponds than in unmanaged ponds because weirs maintain a body of water to dilute incoming tide and rainwater (Herke, 1971). Wintering wading birds and waterfowl prefer weir-managed ponds over unmanaged ponds (Spiller and Chabreck, 1975), and people can travel in weir-managed marshes even during winter. However, weirs obstruct movement of marine organisms (Herke et al., 1987), and there is concern that weirs may promote wetland loss (Nyman et al., 1990a). However, weir-management did not affect marsh loss at Marsh Island, Louisiana (Nyman et al., 1990a).

Louisiana brackish marsh ponds are a stressful environment for aquatic vegetation. Chabreck (1971) found that in coastal ponds between 0.4 ha and 4.0 ha in size, cover by aquatic vegetation averaged 56.4% in fresh marsh but 10.7% in brackish marsh. Species richness is also low in brackish ponds; Chabreck (1971) found 29 species of aquatic vegetation in fresh marsh but only 6 in brackish marsh. These differences might be partly related to greater salinity fluctuations in brackish ponds; salinity can fluctuate from 6 ppt to 11 ppt over a 10-day period (J. A. Nyman, unpubl. data). These differences might also be partly related to the greater tidal action in brackish ponds because it has been suggested that frequent pond drying limits aquatic vegetation in Louisiana marsh ponds (Joanen and Glasgow, 1965).

Even though management for aquatic vegetation is a common practice in the brackish marshes on the Atlantic and Gulf of Mexico coasts of the United States (see articles in Smith et al., 1989), there are few data describing the effects of coastal marsh management on aquatic vegetation. Some sampling of weir-

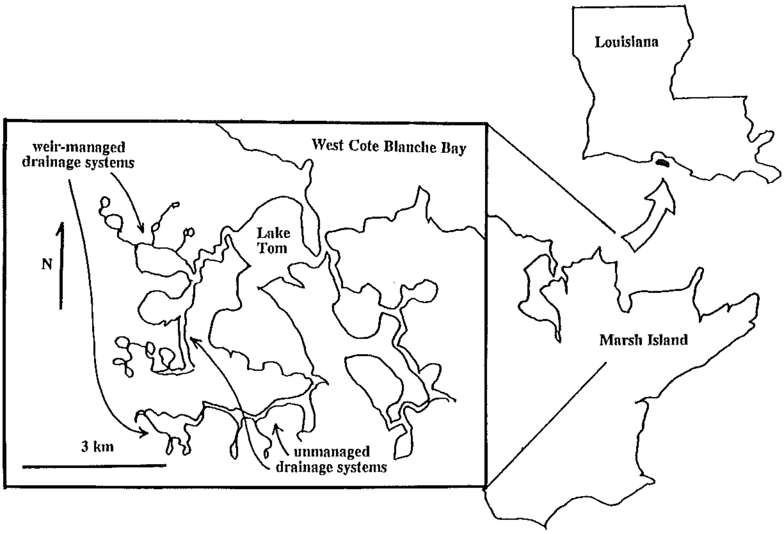

Fig. 1. Location of weir-managed and unmanaged drainage systems, Marsh Island, Louisiana.

managed and unmanaged ponds has been conducted (Chabreck and Hoffpauir, 1962; Louisiana Wild Life and Fisheries Commission, 1964), but those reports are not widely available, and statistical analysis of data is limited to one study of 1½ years' duration (Larrick and Chabreck, 1976). Thus, one purpose of this study was to determine the effects of weir-management on aquatic vegetation at Marsh Island, Louisiana, between 1958 and 1988.

As noted, previous work demonstrated that wintering ducks and wading birds selected weir-managed ponds over unmanaged ponds (Spiller and Chabreck, 1975). During that study, 75.0% of all ducks and coots counted were in weir-managed ponds (Spiller and Chabreck, 1975). However, inferring the value of habitat to wildlife by comparing habitat usage by wildlife to habitat availability has been questioned (Hobbs and Hanley, 1990; Van Horne, 1983), and a more mechanistic approach to habitat evaluation has been suggested (Hobbs and Hanley, 1990). Hobbs and Hanley (1990) recommended that critical resource distribution be examined to collaborate comparisons of habitat use to habitat availability. Wintering waterbird preference for weir-managed ponds might result from altered food resources or merely water availability. Thus, a second purpose of this study was to evaluate the value of any effects on aquatic vegetation to waterfowl management at Marsh Island.

Study Area

Marsh Island is a large island on the central coast of Louisiana, bordered on the south by the Gulf of Mexico and on the north by Vermilion Bay, West Cote Blanche Bay, and East Cote Blanche Bay (Fig. 1). The Marsh Island Wildlife Refuge, operated by the Louisiana Department of Wildlife and Fisheries, includes all of Marsh Island and provides waterfowl with a sanctuary from hunting. Weir construction began in 1958 to improve habitat and attract wintering waterfowl to Marsh Island.

The island consists of approximately 31,000 ha of broad, flat brackish marsh. Elevation averages 30 cm above mean water level and varies little; the only relief is found on the natural levees that can reach 60 cm above mean water level (Orton, 1959). Tide ranges are low, about 30 cm, and water levels are wind-dominated. The climate is humid subtropical with 152–163 cm of precipitation per year, a 300–310-day growing season, and an average annual temperature of 20–21 C (Newton, 1972). The area is subject to winter storms and tropical hurricanes. Persistent north winds associated with winter weather fronts produce extremely low water levels and completely drain many small marsh ponds for several days at a time (Chabreck and Hoffpauir, 1962). There may be 20–30 weather fronts each winter (Huh et al., 1989).

Methods

One large and three small weir-managed ponds and one large and three small unmanaged ponds near the eastern end of the island were studied (Fig. 1). Pond characteristics were similar in weir-managed ponds and un-

TABLE 1. Percent frequency of aquatic vegetation and pond depth in study ponds at Marsh Island, Louisiana, May 1958, before the weirs were completed.

Pond type	*Ruppia maritima*	*Vallisneria americana*	*Eleocharis parvula*	Aquatic coverage	Pond depth (cm)
Managed	18.0	1.4	0.9	20.3	48.8
Unmanaged	18.0	0.3	0.6	18.9	49.8

managed ponds in May 1958, before the weirs were completed (Table 1). These ponds were sampled in 1958, 1959, 1960, 1961, 1962, 1974, 1975, and 1988. Observations collected prior to 1988 have been previously reported but are not widely available, and only 1½ years' observations (1974–75) were statistically analyzed. Earlier sampling included additional drainage systems, but the additional drainage systems were not sampled in 1988 because some initially unmanaged drainage systems had been equipped with weirs, and some of the original weirs showed structural failure. In May 1988, it was found that one of the original small unmanaged ponds had merged with the large unmanaged pond, apparently through shoreline erosion. Thus, only three unmanaged ponds were sampled in May 1988. A suitable replacement pond was selected based on aerial photographs made in 1957 and the replacement pond was sampled when managed and unmanaged ponds were sampled in Oct. 1988.

The same sampling schedule and methods were used to collect all data. Water salinity, turbidity, pond depth, the frequency of aquatic plant coverage, and frequency of individual species of aquatic vegetation were determined in May and Oct. during each year of sampling, except during 1975 when no sampling was done in Oct. The frequency of aquatic plant coverage cannot be estimated from the sum of the frequencies of different species because more than one species occurred at some sampling stations. There was no "mid-growing-season" sampling because aquatic vegetation in Louisiana marsh ponds has distinct fall and spring growing seasons; the cessation of growth during summer has been attributed to high water temperatures that commonly exceed 30 C (Joanen and Glasgow, 1965). Vegetation was sampled with the line-intercept method using two parallel transects extended entirely across each pond. Transects were separated by a distance equal to about one third the pond width. Transects in large ponds (>5 ha) had 50 equally spaced sampling stations; transects in small ponds had 25 equally spaced sampling stations. Sampling was conducted from an airboat because of the extreme shallowness of ponds. At each station, aquatic vegetation was sampled by dragging a garden rake on the pond bottom for about 0.5 m. Care was taken to use the sampling effort at each station. The presence of vegetation was recorded to determine the frequency of aquatic plant coverage. When vegetation was present, the species present were recorded in order to determine the frequencies of individual species. The line-intercept method is well suited for measuring low vegetation (Smith, 1980) and is therefore appropriate for these shallow ponds; the line-intercept method would not be useful in many freshwater ponds where water is deeper and individuals of different species vary greatly in size. At every 5th station, water depth was measured to the nearest 2.5 cm and referenced to the weir crest elevation. A single water sample was collected from mid-depth near the center of each pond and returned to the laboratory, where salinity was determined with a conductivity bridge and turbidity was determined with a Jackson turbidometer.

Paired (managed and unmanaged) seasonal means from 1958, 1959, 1960, 1961, 1962, 1967, 1974, 1975, and 1988 were analyzed to test for differences in aquatic vegetation, salinity, and turbidity between weir-managed and unmanaged ponds. The observations made in May 1958 were not included in statistical analyses because they were made before the weirs were completed. These data were not analyzed with repeated measures because intervals of 5, 11, and 12 years passed between some observations. Instead, these data were analyzed with Wilcoxon's signed-ranks test (Steele and Torrie, 1980), which is nonparametric and does not require that observations are normally distributed (Steele and Torrie, 1980:533). *Myriophyllum spicatum* is an exotic that did not occur when this study was begun; thus, only observations since it was first recorded, May 1974, were analyzed for this species.

Relative sea-level rise and subsequent marsh-surface vertical accretion are extremely rapid on the Louisiana coast (Penland and Ramsey, 1990; Nyman et al., 1990b); thus, it is unlikely that the crests of the weirs were at the same elevation relative to mean water level and marsh elevation as when they were first installed. Thus it was assumed that the weirs no longer restricted water exchange to the same degree as when they were first installed, and it was possible that the functional lifetime of these structures was exceeded. Therefore, data

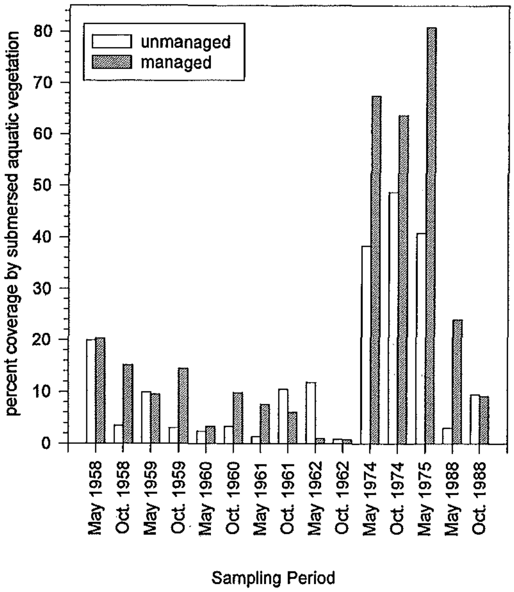

Fig. 2. Mean frequency of coverage by aquatic vegetation in weir-managed and unmanaged ponds between 1958 and 1988, Marsh Island, Louisiana.

collected in 1988 were analyzed to determine if weir-managed and unmanaged ponds differed in aquatic vegetation in 1988. There were not enough pairs of observations to pool and use Wilcoxon's signed-ranks test; thus, these data were analyzed with a two-way ANOVA, with blocking on pond size and season. The pond-size-by-season interaction term was pooled into the error term a priori; treatment-by-block interaction terms were pooled when appropriate (alpha = 0.30). All effects were fixed, type III sums of squares were used to test hypotheses, and an alpha level of 0.05 was used as the critical limit. The assumption of a normal distribution of data was suspect because these were percentage data that often ranged from 0–30% (Steele and Torrie, 1980). Therefore, before parametric statistics were used, the assumption of a normal distribution of data was tested by determining the normality of the residual error terms with Proc Univariate of SAS. The S-statistic (alpha = 0.2000), the plot of residuals, and the box plot were all considered when deciding if a variable was normally distributed. *Potamogeton pusillus* was log-transformed to achieve a normal distribution.

Results

Data from 1958 through 1988.—Frequency of aquatic plant coverage was quite variable (Fig. 2) and greater in weir-managed ponds than in unmanaged ponds ($P < 0.05$). Averaged over all dates, coverage by aquatic vegetation was 1.7 times greater in weir-managed ponds than in unmanaged ponds (Table 2).

Weir-managed ponds contained more *R. maritima* than unmanaged ponds ($P < 0.01$). Averaged over all dates, *R. maritima* was 2.7 times more frequent in weir-managed ponds than in unmanaged ponds (Table 2). At certain times there were great differences between weir-managed and unmanaged ponds, at other times there was little or no difference (Fig. 3). *R. maritima* was the most frequent spe-

Table 2. Frequency of aquatic species, frequency of plant coverage, and water characteristics in weir-managed and unmanaged ponds averaged over 14 sampling dates between Oct. 1958 and Oct. 1988, Marsh Island, Louisiana.

	Unmanaged mean (SE)	Managed mean (SE)
Vegetation		
Myriophyllum spicatum[a]	21.2 (8.5)[b]	36.4 (11.8)
Ruppia maritima	2.5 (0.8)[b]	6.8 (1.5)
Vallisneria americana	1.5 (0.3)	1.2 (0.2)
Ceratophyllum demersum	0.4 (0.3)[b]	3.7 (1.8)
Eleocharis parvula	0.3 (0.1)[b]	0.1 (0.1)
Najas quadalupensis	0.1 (0.1)	0.1 (0.1)
Aquatic plant coverage	13.4 (4.4)[b]	22.3 (7.2)
Water		
Salinity (ppt)	3.2 (0.7)	3.2 (0.7)
Turbidity (ppm)	40.6 (5.0)	37.4 (4.4)

[a] *Myriophyllum spicatum* did not occur until 1974; thus, these estimates are based on 5 observations rather than 14. It has been very frequent since it arrived, which also explains why average frequency of *Myriophyllum spicatum* is greater than average plant coverage averaged over 1958–88.

[b] Denotes significant difference between weir-managed ponds and unmanaged ponds.

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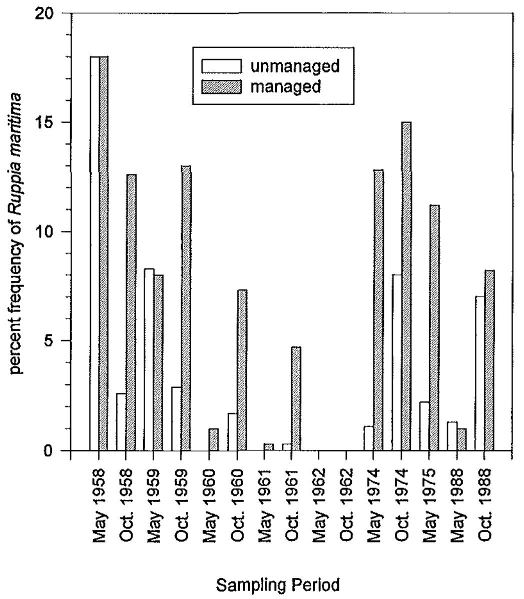

Fig. 3. Mean frequency of *Ruppia maritima* in weir-managed and unmanaged ponds between 1958 and 1988, Marsh Island, Louisiana.

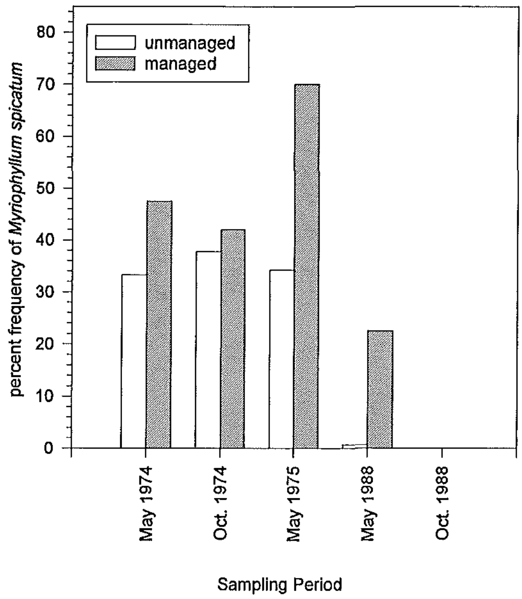

Fig. 4. Mean frequency of *Myriophyllum spicatum* in weir-managed and unmanaged ponds between 1958 and 1988, Marsh Island, Louisiana.

cies prior to 1962, but has usually been only the second most frequent plant since 1974.

Estimated frequency of *M. spicatum* was greater in weir-managed ponds than in unmanaged ponds on all sampling dates, except during Oct. 1988 when it was absent from both managed and unmanaged ponds (Fig. 4); however, only five sampling dates have occurred since *M. spicatum* was first recorded and there were not enough paired observations for statistical tests. Overall, *M. spicatum* was 1.7 times more frequent in weir-managed ponds than in unmanaged ponds, but in May 1988 it was 32.1 times more frequent in weir-managed ponds than in unmanaged ponds (Table 2). It is not known when *M. spicatum* first appeared on Marsh Island, but it does not appear to have greatly affected other species of aquatic vegetation, as both *R. maritima* and *Ceratophyllum demersum* were also abundant in 1974–75 (Figs. 3, 5), and *R. maritima* was the most frequent species in fall of 1988.

In addition to dominant species, some other species also differed between weir-managed and unmanaged ponds. *Ceratophyllum demersum* was 9.2 times more frequent in weir-managed ponds than in unmanaged ponds ($P < 0.01$) (Table 2), but its occurrence was variable (Fig. 5). Weir-managed ponds contained less *Eleocharis parvula* than unmanaged ponds ($P < 0.02$). *Eleocharis parvula* did not occur at more than 2% of the sampling stations and has been absent from weir-managed ponds and unmanaged ponds on all sampling dates since 1962 (Fig. 6).

Weir-management did not account for sig-

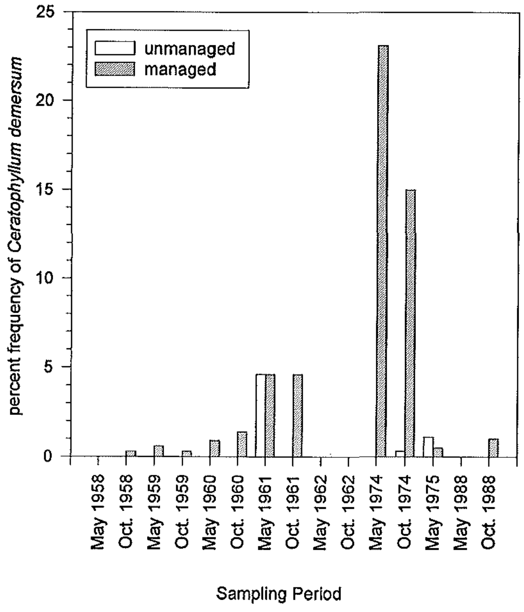

Fig. 5. Mean frequency of *Ceratophyllum spicatum* in weir-managed and unmanaged ponds between 1958 and 1988, Marsh Island, Louisiana.

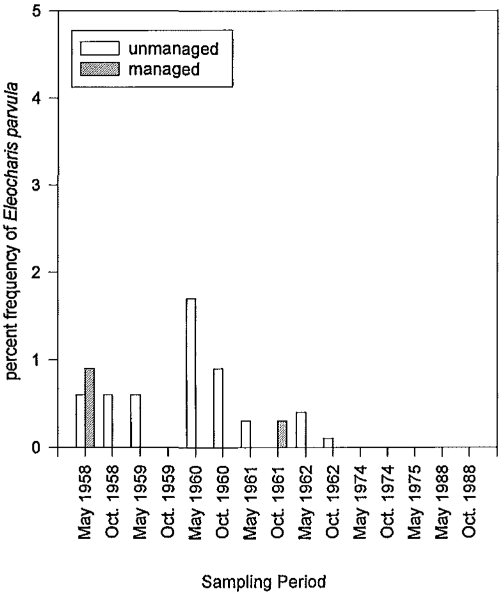

Fig. 6. Mean frequency of *Eleocharis parvula* in weir-managed and unmanaged ponds between 1958 and 1988, Marsh Island, Louisiana.

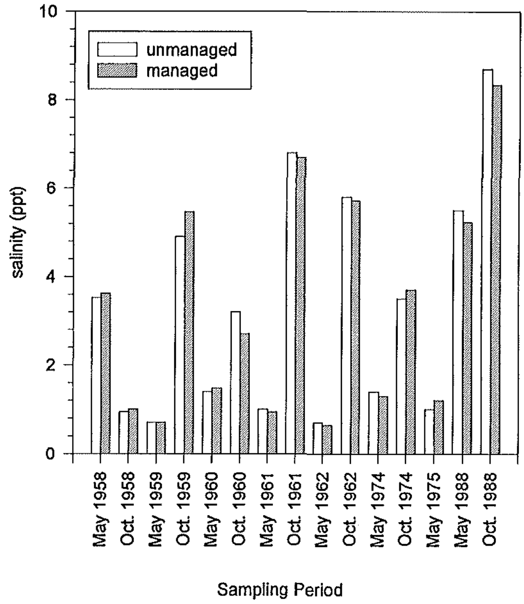

Fig. 8. Mean salinity in weir-managed and unmanaged ponds between 1958 and 1988, Marsh Island, Louisiana.

nificant variation in other plant species, salinity, or turbidity. Salinity and turbidity have undergone great seasonal variation each year, with salinity lower and turbidity greater in the spring (Figs. 7, 8).

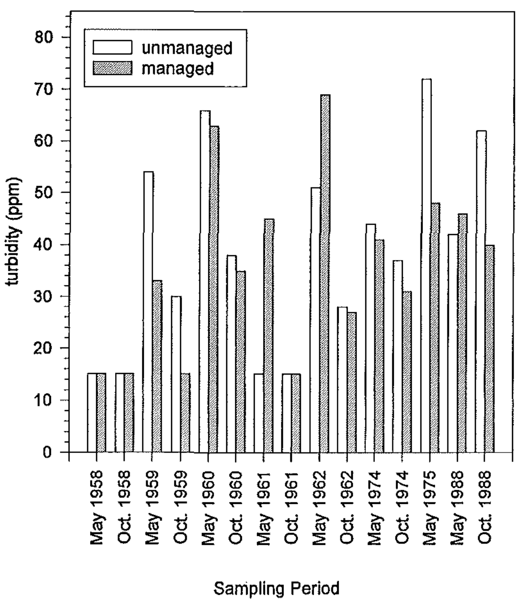

Fig. 7. Mean turbidity in weir-managed and unmanaged ponds between 1958 and 1988, Marsh Island, Louisiana.

Data collected in 1988.—Algae and four vascular plant species were found in the ponds in 1988 (Table 3). *Myriophyllum spicatum* dominated the spring growing season in managed ponds and *R. maritima* dominated the fall growing season in managed and unmanaged ponds. Weir-managed ponds contained significantly more *M. spicatum* than did unmanaged ponds because of the great abundance in the spring (F = 6.51, 1 and 10 df, P = 0.0288). Notably, there was no difference in pond depth between weir-managed and unmanaged ponds (F = 0.10, 1 and 11 df, P = 0.7576). A difference in average pond depth between May and Oct. probably resulted from error in estimating water levels over the weir crest in Oct. At that time, water was rushing over the weir and may have led to incorrect measurements. Assuming that the May estimate of depth was more accurate, pond bottoms accreted approximately 10 cm since the weirs were completed in response to increasing sea level and sedimentation in marsh ponds (Tables 1, 3). Turbidity appeared to be higher in unmanaged ponds than in managed ponds during Oct. (Table 3), but the difference was not significant (F = 1.19, 1 and 10 df, P = 0.3043).

Discussion

1958–88 data.—Weir-management greatly increased amounts of *R. maritima*, *M. spicatum*,

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TABLE 3. Frequency of aquatic plant species, frequency of aquatic plant coverage, and water characteristics in four weir-managed (W) and four unmanaged (U) ponds, Marsh Island, Louisiana, 1988.

	May		October	
	U mean (SE)	W mean (SE)	U mean (SE)	W mean (SE)
Vegetation				
Myriophyllum spicatum[a]	0.7 (0.7)	22.5 (7.8)	0.0	0.0
Ruppia maritima	1.3 (1.3)	1.0 (1.0)	7.0 (4.1)	8.2 (5.6)
Vallisneria americana	1.3 (1.3)	1.0 (1.0)	2.5 (2.5)	0.0
Ceratophyllum demersum	0.0	0.0	0.0	1.0 (1.0)
Aquatic coverage	3.0 (1.5)	24.0 (8.5)	9.5 (3.4)	9.2 (5.2)
Algae	1.0 (0.6)	0.5 (0.5)	0.0	0.0
Water				
Salinity (ppt)	5.5 (0.1)	5.2 (0.6)	8.7 (0.1)	8.3 (0.3)
Turbidity (ppm)	42.0 (2.0)	45.8 (8.7)	61.5 (8.3)	40.2 (5.0)
Depth (cm)	38.0 (20.2)	39.8 (15.1)	51.8 (11.6)	49.2 (8.1)

[a] Denotes significant difference between weir-managed ponds and unmanaged ponds.

and *C. demersum* in ponds; however, the amounts of each species varied greatly among sampling dates, as did the magnitude of the difference between weir-managed and unmanaged ponds. Evidently, weir-management promoted aquatic vegetation by modifying environmental factors that are not the most important regulators of aquatic plant growth. An agricultural analogy is that fertilizers do not greatly affect crop growth unless water availability is within a certain range. Unfortunately, little is known about the factors regulating aquatic plant growth in this dynamic system other than that turbidity is believed to be especially important. More frequent sampling would likely be required to detect small differences in turbidity between weir-managed and unmanaged ponds. We have no explanation for the extremely high abundance throughout 1974–75; however, this was a period of higher than normal water levels that was associated with increased productivity in estuarine systems (Morris et al., 1990).

Ruppia maritima and *C. demersum* are native plants that are abundant in coastal marshes, but *M. spicatum* is an exotic. It is not known when *M. spicatum* first appeared on Marsh Island or what effects it may have had on other species of aquatic vegetation at Marsh Island. Larrick and Chabreck (1976) reported that it had been present for several years before 1974, but it was not recorded in 1962. Although *M. spicatum* can almost completely replace native vegetation stands in freshwater lakes within 3 years (e.g., Madsen et al., 1991), our data show that it has not replaced native vegetation in these brackish ponds even though it has been present for at least 15 years.

Coastal submergence may be related to the absence of *E. parvula* on all sampling dates since 1962. *Eleocharis parvula* is a sedge that depends on water level fluctuations, rather than on water quality parameters, to persist in ponds (Davis and Brinson, 1980). Absence of pond drainage in weir-managed ponds evidently reduced *E. parvula* establishment during the late 1950s and early 1960s. Since then, subsidence and sea-level rise may have been great enough to prevent complete drainage even of unmanaged marsh ponds, thus preventing the establishment of *E. parvula*. Pond depths indicate that the pond bottoms accreted 10 cm between 1958 and 1988, but ^{137}Cs dating indicates that the marsh surface accreted 15 cm since then (Nyman et al., in press), which suggests that pond bottoms have not kept pace with relative sea-level rise. *Eleocharis parvula* has not disappeared from Marsh Island; it was observed at many locations throughout the emergent plant community (Nyman et al., 1993).

1988 data.—The weirs were resurveyed in 1988, and it was found that the elevation of the weir crests had changed from the original −15 cm to approximately −30 cm relative to the marsh surface (R. H. Chabreck, unpubl. data). This agreed with the estimated vertical accretion, which located the 1963 marsh surface approximately 15 cm below the 1990 marsh surface (Nyman et al., 1994). Tide-gauge data and pond-bottom contours of Chabreck et al. (1979) indicate that this should cause about 25%, rather than 13%, of the weir-managed pond area to drain during low water. Thus, twice as much pond area is probably draining as was intended. The lower crest may also allow twice as much water exchange as was intended. Field observations indicate that even though the weirs had lost elevation relative to mean water level and the marsh surface, they were still restricting water exchange in 1990. Weir-managed ponds did not completely drain (M. Carloss, Louisiana Department of Wildlife and Fisheries, pers. comm.) and exhibited lower rates of short-term salinity fluctuations than did unmanaged ponds (unpubl. data, Louisiana Department of Wildlife and Fisheries). Furthermore, as shown by the data collected in 1988, weir-managed ponds contained 32 times more *M. spicatum* than did unmanaged ponds in 1988. Thus, positive effects were obtained with a greater degree of water exchange than was originally designed, which suggests that coastal marsh managers might be able to increase production of aquatic vegetation while using vertical slots or other modifications to weirs that allow greater water exchange. Increasing water exchange is desirable because weirs reduce use of ponds as nursery habitat by estuarine dependent fish and crustaceans (Herke et al., 1987), and thus may reduce estuarine-dependent fisheries where nursery habitat limits populations. The fact that weir-managed ponds and unmanaged ponds were the same depth in 1988 suggests that weir-management since 1958 has not affected sedimentation in these marsh ponds. If weir-management affected sedimentation, there should have been a large difference in depth between weir-managed ponds and unmanaged ponds after 30 years.

Implications for waterfowl management.—Aquatic vegetation is an important component of mottled duck (*Anas fulvigula maculosa*) breeding habitat in Louisiana. A strong positive relationship exists between the amount of aquatic vegetation and the number of mottled duck broods in fresh, intermediate, and brackish Louisiana coastal marsh (Esters, 1988). This may be partly related to the high correlation observed between aquatic invertebrates and aquatic vegetation (Esters, 1988). Thus, increases in aquatic vegetation likely benefited breeding resident ducks.

Increased aquatic vegetation likely benefited wintering migrant ducks as well as resident species. Over two thirds of the entire Mississippi Flyway duck population, over four million ducks, winter in Louisiana coastal marshes (see Chabreck et al., 1989). Paulus (1982), citing unpublished data, reported that over one third of the wintering ducks in southwestern Louisiana were gadwalls (*Anas strepera*), and found that this species fed almost entirely on aquatic vegetation. Aquatic vegetation is also important to species such as American widgeon (*Anas americana*) and shoveler (*Anas clypeata*) that winter in Louisiana (Chabreck et al., 1989). Duck use of aquatic vegetation depends partly on the amounts present; evidently, if biomass is too low, foraging efficiency is too low to warrant use of it (Paulus, 1982). This behavior by wintering ducks is not limited to aquatic vegetation; a similar relationship exists between mast availability and mast use (Reinecke et al., 1989). Increased aquatic vegetation thus likely increased wintering habitat quality, which may improve subsequent reproductive success of these ducks, which depends partly on wintering habitat quality (Heitmeyer and Fredrickson, 1981; Weller and Batt, 1988).

In addition to the amounts present, duck use of aquatic vegetation depends on the species present. *Ruppia maritima* is an important duck food in Louisiana brackish marsh. Martin and Uhler (1939) found that *R. maritima* was the plant used in greatest abundance by ducks along the Gulf of Mexico coast, and *R. maritima* has been shown to be an important food of ducks wintering in Louisiana (Beter, 1957; Chamberlain, 1959). Weir-managed ponds also contained more *C. demersum* than unmanaged ponds. Ducks also eat *C. demersum*, but it does not appear to be an important or preferred food in Louisiana brackish marsh (Paulus, 1982).

Myriophyllum spicatum has been considered a threat to diving duck habitat in the north-central United States (Korschgen, 1989). However, it may enhance habitat quality in reservoirs and lakes of the southeastern United States (Johnson and Montalbano, 1989), and Florshutz (1972) reported that waterfowl numbers increased after the plant spread into Back Bay National Wildlife Refuge on the Virginia coast. In that study, *M. spicatum* accounted for 33% of the volume of foods consumed by waterfowl (Florschutz, 1972). Apparently, the value of the plant cannot be judged outside the context of the habitat under discussion. In Louisiana brackish marshes, *M. spicatum* is an important duck food. Vaughn (1977) showed that *M. spicatum* was an important food of species wintering in Louisiana, such as gadwall (ranked number 2, accounting for 19% of food volume, $n = 48$) and green-winged teal (*Anas crecca*) (ranked number 2, accounting for 15% of food volume, $n = 42$).

Not only are *R. maritima* and *M. spicatum* important foods, they are also preferred foods in

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tidal brackish marshes. Paulus (1982) reported that both of these species was preferred foods of gadwalls wintering in Louisiana tidal brackish marshes, and suggested management for these species between Oct. and April. Thus, weir-management likely increased habitat quality for wintering ducks by increasing *R. maritima* and *M. spicatum,* which may partly explain the observed preference that wintering ducks have for weir-managed ponds (Spiller and Chabreck, 1975).

Eleocharis parvula was the second most important food in the study of wintering gadwalls in Louisiana by Paulus (1982), but it was not a preferred food. It was fed on only after more preferred foods such *R. maritima* and *M. spicatum* became unavailable, and may have been inadequate in meeting dietary requirements as the birds switched to algae as soon as it became available. Thus, the reduction in frequency of this plant in the early 1960's may have had a small negative effect on habitat quality, but that effect was likely offset by increases in *R. maritima. Eleocharis parvula* has not occurred, even in unmanaged ponds, on any sampling date since 1962; thus, any negative effect of weir-management ceased when it disappeared from unmanaged ponds. Should *E. parvula* reappear in the unmanaged ponds, these areas may provide some food for ducks when other foods are lacking; however, little of this plant can be expected from these ponds because it never occurred at more than 2% of the sampling stations in the past.

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Literature Cited

Beter, R. A. 1957. A comparative winter food habit study of dabbling ducks from the brackish Lake Borgne marsh of St. Bernard Parish and fresh marsh of Pass A Loutre (Miss. Delta) Plaquemines Parish, Louisiana. M.S. thesis, Louisiana State Univ., Baton Rouge, LA.

Chabreck, R. H. 1971. Ponds and lakes of the Louisiana coastal marshes and their value to fish and wildlife. Proc. Ann. Conf. Southeastern Assoc. Game Fish Comm. 25:206–215.

———, R. J. Hoar, and W. D. Larrick, Jr. 1979. Soil and water characteristics of coastal marshes influenced by weirs, p. 129–145. *In:* Proc. Third Coastal Marsh and Estuary Management Symposium. J. W. Day, D. D. Culley, R. E. Turner, and A. J. Mumphrey, Jr. (eds.). Louisiana State University Division of Continuing Education, Baton Rouge, LA.

———, and C. M. Hoffpauir. 1962. The use of weirs in coastal marsh management in Louisiana. Proc. Ann. Conf. Southeastern Assoc. Game Fish Comm. 16:103–112.

———, T. Joanen, and S. L. Paulus. 1989. Southern coastal marshes and lakes, p. 249–277. *In:* Habitat management for migrating and wintering waterfowl in North America. L. M. Smith, R. L. Pederson, and R. M. Kaminski (eds.). Texas Tech University Press, Lubbock, TX.

Chamberlain, J. L. 1959. Gulf coast marsh vegetation as food of wintering waterfowl. J. Wildl. Manage. 23(1):97–102.

Davis, G. J., and M. M. Brinson. 1980. Responses of submerged vascular plant communities to environmental change. Biol. Serv. Prog., U.S. Fish and Wildl. Serv., U.S. Dept. Interior. FWS/OBS-79/33.

Esters, M. D. 1988. Habitat use by mottled duck broods. M.S. thesis, Louisiana State Univ., Baton Rouge, LA.

Florshutz, O., Jr. 1972. The importance of Eurasian milfoil (*Myriophyllum spicatum*) as a waterfowl food. Proc. Ann. Conf. Southeastern Assoc. Game Fish Comm. 26:189–191.

Heitmeyer, M. E., and L. H. Fredrickson. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Trans. N. Am. Nat. Resourc. Conf. 46:44–57.

Herke, W. H. 1971. Use of natural, and semi-impounded, Louisiana tidal marshes as nurseries for fishes and crustaceans. Ph.D. diss., Louisiana State Univ., Baton Rouge, LA.

———, E. E. Knudsen, P. A. Knudsen, and B. D. Rogers. 1987. Effects of semi-impoundment on fish and crustacean nursery use: evaluation of a "solution." Coastal Zone '87 5:2562–2576.

Hobbs, N. T., and T. A. Hanley. 1990. Habitat evaluation: do use/availability data reflect carrying capacity? J. Wildl. Manage. 54(4):515–522.

Huh, O. K., L. J. Rouse, H. H. Roberts, S. A. Hsu, and D. A. Rickman. 1989. Cold front passages and the response of coastal water and sediment: Mississippi Delta plain region, USA. *In:* U.S. Fish and Wildlife Service and the State of Louisiana. Abstracts from the 3rd annual workshop on remote sensing and geographic information systems for coastal management in Louisiana. U.S. Fish Wildl. Serv. NRC open file report 89-01.

Joanen, T., and L. L. Glasgow. 1965. Factors influencing the establishment of widgeongrass stands in Louisiana. Proc. Southeastern Assoc. Game Fish Comm. 19:78–92.

Johnson, F. A., and F. Montalbano. 1989. Southern reservoirs and lakes, p. 93–116. *In:* Habitat management for migrating and wintering waterfowl in North America. L. M. Smith, R. L. Pederson, and R. M. Kaminski (eds.). Texas Tech Univ. Press, Lubbock, TX.

Korschgen, C. E. 1989. Riverine and deepwater habitats for diving ducks, p. 157–180. *In:* Habitat management for migrating and wintering waterfowl in North America. L. M. Smith, R. L. Pederson, and R. M. Kaminski (eds.). Texas Tech Univ. Press, Lubbock, TX.

LARRICK, W. D., AND R. H. CHABRECK. 1976. Effects of weirs on aquatic vegetation along the Louisiana coast. Proc. Ann. Conf. Southeast Game Fish Comm. 13:100–115.

LOUISIANA WILD LIFE AND FISHERIES COMMISSION. 1964. Annual progress report, W-29-R-II. Louisiana Wild Life and Fisheries Commission. Wild Life and Fisheries Building, 400 Royal St., New Orleans, LA.

MADSEN, J. D., J. W. SUTHERLAND, J. A. BLOOMFIELD, L. W. EICHLER, AND C. W. BOYLEN. 1991. The decline of native vegetation under dense Eurasion Watermilfoil canopies. J. Aquat. Plant Manage. 29: 94–99.

MARTIN, A. C., AND F. M. UHLER. 1939. Food of game ducks in the United States and Canada. U.S. Dept. Agric. Tech. Bull. No. 634.

MORRIS, J. T., B. KJERFVE, AND J. M. DEAN. 1990. Dependence of estuarine productivity on anomalies in mean sea level. Limnol. Oceanogr. 35(4):926–930.

NEWTON, M. B., JR. 1972. Atlas of Louisiana. A guide for students. Geoscience Publications, Louisiana State University, Baton Rouge, LA.

NYMAN, J. A., R. H. CHABRECK, AND G. LINSCOMBE. 1990a. Effects of weir management on marsh loss, Marsh Island, La., USA. Environ. Manage. 14(6): 809–814.

———, R. D. DELAUNE, AND W. H. PATRICK, JR. 1990b. Wetland soil formation in the rapidly subsiding Mississippi River Deltaic Plain: mineral and organic matter relationships. Est. Coastal Shelf Sci. 31:57–69.

———, R. H. CHABRECK, AND N. KINLER. 1993. Some effects of herbivory and 30 years of weir management on emergent vegetation in a brackish marsh. Wetlands. 13(3):165–175.

———, M. CARLOSS, R. D. DELAUNE, AND W. H. PATRICK, JR. 1994. Erosion rather than plant dieback as the mechanism of marsh loss in an estuarine marsh. Earth Surface Processes and Landforms. 19:69–84.

ORTON, E. W. 1959. A geological study of Marsh Island, Iberia Parish, Louisiana. La. Wild Life Fish. Comm. New Orleans, LA.

PAULUS, S. L. 1982. Feeding ecology of gadwalls in Louisiana in winter. J. Wildl. Manage. 46(1):71–79.

PENLAND, S., AND K. E. RAMSEY. 1990. Relative sea-level rise in Louisiana and the Gulf of Mexico. J. Coastal Res. 6:323–342.

REINECKE, K. J., R. M. KAMINSKI, D. J. MOORHEAD, J. D. HODGES, AND J. R. NASSAR. 1989. Mississippi Alluvial Valley, p. 203–247. *In:* Habitat management for migrating and wintering waterfowl in North America. L. M. Smith, R. L. Pederson, and R. M. Kaminski (eds.). Texas Tech Univ. Press, Lubbock, TX.

SMITH, L. M., R. L. PEDERSON, AND R. M. KAMINSKI. 1989. Habitat management for migrating and wintering waterfowl in North America. Texas Tech Univ. Press, Lubbock, TX.

SMITH, R. L. 1980. Ecology and field biology. Third ed. Harper and Row, New York.

SPILLER, S. F., AND R. H. CHABRECK. 1975. Wildlife populations in coastal marshes influenced by weirs. Proc. Ann. Conf. Southeastern Assoc. Game Fish Comm. 29:518–525.

STEELE, R. G. D., AND J. H. TORRIE. 1980. Principles and procedures of statistics. A biometrical approach. McGraw-Hill, New York.

VAN HORNE, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893–901.

VAUGHN, J. A. 1977. An examination of the contents of duck gizzards from Carrion Crow Bayou, Terrebonne Parish, Louisiana during the 1975 and 1976 hunting seasons. M.S. thesis, Louisiana State Univ., Baton Rouge, LA.

WELLER, M. W., AND B. D. J. BATT. 1988. Waterfowl in winter: past, present and future. *In:* Waterfowl in winter. M. W. Weller (ed.). University of Minnesota Press, Minneapolis.

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