The Effect of Long-Term Marsh Management on Land-Loss Rates in Coastal Louisiana

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ABSTRACT / Louisiana's coastal wetlands have been actively and passively managed since the 1950s to reduce land loss, change plant composition, control water levels, and determine property boundaries, among other reasons. Marsh management is the primary technique that has been used in Louisiana to try to slow or halt dramatic wetland losses (0.8%/yr from 1955 to 1978, or 288,000 ha). Because of the large amount of Louisiana's coastal wetlands under management and the high cost associated with marsh management, it is important to determine if those efforts have been successful. The purpose of this study was to determine if land-loss rates were changed as a result of marsh management. This study used data from a previous study and additional new data. Data for 13 paired managed and unmanaged sites (total area $= 22 \times 10^3$ ha) studied previously were obtained, expanded, and tested statistically to provide empirically valid conclusions over a longer management period than previously available (1–32 years compared to 6–37 years). There was no statistically significant difference between managed and nearby reference sites. The effects of changes in the regional environment appear to have had much greater influence on the land-loss rates than did management at individual sites.

Louisiana has nearly 41% of the US coastal wetlands (Turner 1990). However, because of a number of factors not encountered elsewhere, the average annual rate of loss is about 0.86%, or 12,540 ha/yr (Turner 1990). There have been numerous efforts to slow or reverse these losses because of the role that coastal wetlands play in fisheries production, storm/flood protection, recreational activities, etc. Marsh management, using various water-control structures, is one of the more conspicuous approaches applied. To slow or halt land loss in Louisiana, marsh management is primarily accomplished through water-level control using levees and some type of water-control structure. Management techniques in Louisiana range from passive, nonadjustable structures to actively adjusted structures and levees for seasonal water control (Cowan and others 1988). From 1980 to 1988, the Louisiana Department of Natural Resources, Coastal Management Division, received 165 applications to manage 203,000 ha (503,000 ac) in addition to the 141,000 ha (350,000 ac) already under management (Cahoon and others 1990). Currently, Louisiana has nearly 20% of its coastal wetlands under some type of management (Cowan and others 1988; Boumans and Day, 1994) with a variety of goals, including reducing saltwater intrusion, improving wildlife habitats, and supporting mineral exploration and urbanization (Cowan and others 1988). This large area of the coast and the possible conflicts between owner and user desires, such as access to the property for wildlife harvesting; the management goals, such as land loss reduction and wildlife exclusion; and, the interpretation of their results have resulted in a complex arena for marsh management (Cowan and others 1988).

KEY WORDS: Marsh management; Land loss; Louisiana; Weirs; Levees; Spoil banks

There are no conclusive data analyses to demonstrate that marsh management practices have reduced wetland losses (Cowan and others 1988; Boumans and Day, 1994; Turner and others 1989). An EPA member review of the scientific literature concerning marsh management suggests that the current practices have a negative impact on several important wetland functions (Anon, 1994). Sweeney and others (1990), in a study using aerial imagery analysis, reported that these types of marsh management practices (active and/or passive) resulted in both land gain and/or land loss. Their results may be partially a consequence of the relatively short period of management operations in many of the sites—half of the 16 sites had been under management less than four years.

The Sweeney and others (1990) study took aerial photos of the sites for 1955, 1978, 1983, 1985, and 1988 and determined changes in habitat area, salinity, and land-to-water ratios (Figure 1). Of the 16 sites studied, results showed that only two sites, L. H. Ryan and Creole Canal, showed "significant" changes in marsh to water ratio ("significant" defined by them as >3% gain). However, management success was impossible to establish for those two sites because they had been under management less than three years. Furthermore, they

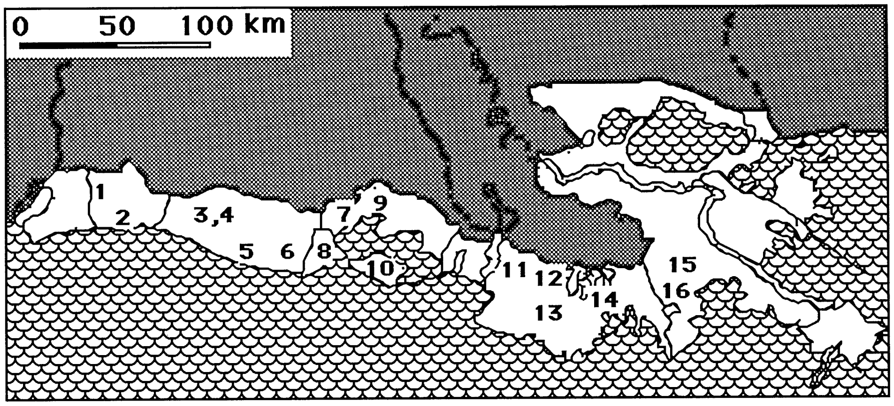

Figure 1. The location of the study sites. Site numbers are identical to those used by Sweeney and others (1990).

did not subject the results to a statistical analysis, which would help identify causal factors.

This study is a follow-up on that aerial imagery analysis of Sweeney and others (1990). New data were acquired for 1992–1993 and interpreted to add another five years of management for analysis. Two different statistical analyses of the data were made to test for differences between sites under management and unmanaged sites over longer time periods.

Methods

Thirteen of the original 16 marsh management sites studied by Sweeney and others (1990) were used in this study. The other three sites (no. 8 State Wildlife Refuge; no. 9 McIlhenny Company, and; no. 13 Louisiana Land & Exploration) were not used because their boundaries could not be accurately determined, and the new data could not be accurately plotted. Management activities at the 13 sites used range in duration from six to 37 years. The sites studied are listed in Table 1, and their locations are indicated in Figure 1. Additional data used was 1992–1993 Landsat Thematic Mapper imagery consisting of RGB bands 753 composite, with 25-m cells. The total area of all sites examined was 12,790 ha and 9532 ha for the managed and references sites, respectively. The site descriptions and management goals for each site are primarily based on those identified in Sweeney and others (1990).

Data Sources and Analyses

The Louisiana Department of Natural Resources (DNR) supplied data on the original study sites. The current Thematic Mapper data was plotted to match the scale of DNR maps and the site boundaries. A point grid method was used to determine land to water ratios. The point grid method was tested by Gagliano and van Beek (1970) and was determined, through statistical analysis, to have the same accuracy as the planimetering method (Gagliano and van Beek 1970). A 16 lines per inch Chartpak Pattern Film grid (cat. no. PT084) was randomly placed over each site, taped in place, and dots counted as either land or water as indicated by the color in the image. When a dot happened to be located on the boundary of land and water, it was always counted as water. Likewise, when a dot was located on the site boundary, it was included in the study site count. Sweeney and others (1990) referred to the paired studied sites as either ''plan'' or ''control'' sites. However, there were no true control sites, in an experimental sense, but rather nearby reference sites. In this study these paired sites will be referred to as either ''managed'' or ''reference'' sites, respectively.

Two different statistical analyses were made to determine the significance of management using a standard statistical analysis package (SAS 1990a,b,c). Both analyses used a ''change point'' model for the linear regressions (Figure 2). For the first model (full model), a linear regression was run on the log of the land-to-water ratios using two variables for the managed site that forced the slope of the premanagement data of the managed site to take the same slope as that of the reference site, but with a separate intercept. The slope of the postmanagement era data of the managed site could take a slope different from that of the reference site, which would reflect management effects. The null hypothesis of this full model forced the slopes of both the managed and reference sites to be equal for both pre- and postmanagement era data and allowed only the intercepts to differ.

The second analysis was accomplished to check the results obtained in the first analysis. This analysis ran a reduced model (one variable) on the change in the land-to-water ratios using the log of the ratios. This

Table 1. Study site locations, size, vegetative cover, management measures, major structure types, objectives, and year of implementation[a]

Site	Site name	Location	Size (ha)	Vegetation type	Type of management	Structure type	Number	Objective	Year of implementation
1M	Amoco West Black Lake	Chenier Plain	2741	Fresh	A	FG, VC, P	9	H, LL	1987
1R	Amoco West Black Lake	Chenier Plain	1305	Fresh					
2M	Creole Canal	Chenier Plain	1131	Brackish	A	FG, VC	4	H, LL	1985
2R	Creole Canal	Chenier Plain	734	Brackish					
3M	Little Pecan Unit 6	Chenier Plain	173	Fresh	A	F, VC	1, 1	LL, H	1978
3R	Little Pecan Unit 6	Chenier Plain	163	Fresh					
4M	Little Pecan Unit 9	Chenier Plain	450	Fresh	A	FG	2	LL	1977
4R	Little Pecan Unit 9	Chenier Plain	399	Fresh					
5M	Rockefeller Refuge	Chenier Plain	2084	Brackish	A	FG, VC	2	H	1958
5R	Rockefeller Refuge	Chenier Plain	1604	Brackish					
6M	Vermilion Corp.	Chenier Plain	379	Intermediate	A	DG	1	LL, H	1966
6R	Vermilion Corp.	Chenier Plain	156	Fresh					
7M	Vermilion Bay Land	Delta Plain	444	Brackish	A	FG, VC	1, 3	H	1987
7R	Vermilion Bay Land	Delta Plain	282	Intermediate					
8M	State Wildlife Refuge	Chenier Plain	1470	Brackish	P	FC	2	H	1967
8R	State Wildlife Refuge	Chenier Plain	1540	Brackish					
9M	McIlhenny Company	Delta Plain	793	Intermediate	P	FC	3	H	1983
9R	McIlhenny Company	Delta Plain	867	Intermediate					
10M	Marsh Island Refuge	Delta Plain	680	Brackish	P	FC	1	H	1959
10R	Marsh Island Refuge	Delta Plain	749	Brackish					
11M	Avoca Bayou Lawrence	Delta Plain	248	Fresh	A	VC, FG	2, 1	LL, H	1987
11R	Avoca Bayou Lawrence	Delta Plain	261	Fresh					
12M	Fina Falgout Canal	Delta Plain	2768	Fresh	A	FC, VC	4, 1	LL	1985
12R	Fina Falgout Canal	Delta Plain	692	Fresh					
13M	La. Land & Explor.	Delta Plain	3001	Intermediate	P	FC, PG	20, 3	LL, H	1956
13R	La. Land & Explor.	Delta Plain	2270	Brackish					
14M	Fina Bayou Chauvin	Delta Plain	241	Fresh	P	FC	2	LL	1984
14R	Fina Bayou Chauvin	Delta Plain	273	Fresh					
15M	L.H. Ryan	Delta Plain	92	Brackish	A	FG, VC	2	LL, H	1984
15R	L.H. Ryan	Delta Plain	210	Brackish					
16M	Lafourche Realty Co.	Delta Plain	1359	Intermediate	P	SFC, CL	4, 2	LL, H	1984
16R	Lafourche Realty Co.	Delta Plain	2704	Fresh					

[a]Site: M, managed site; R, reference site. Type of management: A, active; P, passive. Structure type: FG, flap gated culvert; FC, fixed crest weir; FV, flap-gated structure with a variable-crest weir on the other end; DG, double flap-gated culvert; VC, variable-crest weir; PG, plugs, dikes, or dams; SFC, slotted fixed-crest weir; CL, culvert; Objective (major): H, habitat (waterfowl, fur-bearer, indigenous wildlife, or fish); LL, land loss.

approach addresses the difficulties associated with the very large relative ratios and resulting effects on the regression slopes from the 1955–1956 sampling period. Because the 1955–1956 ratios were dramatically high in comparison to all other sampling periods, it was felt that those ratios may have had effects on the regression slopes that inappropriately altered the results. This second full model tests for a difference in the change of ratios between managed and reference sites after the point of management by forcing the slope of the premanagement era equal to zero. The slope was allowed to be other than zero after the point of management; if there were a difference in the slopes, then management did have an effect. The reduced model forced both pre- and postmanagement era slopes to equal zero (null hypothesis).

Results

General Results

Only three managed sites (Little Pecan Unit 6, Marsh Island Refuge, and Fina La Terre) had any apparent increase in land-to-water ratios (Figure 3). The reference sites of the above sites plus two additional reference sites (Avoca Bayou Lawrence and Fina Bayou Chauvin) showed some increase in their ratios.

Visual inspection and comparison of the aerial imagery indicate that none of the changes in land-to-water ratios at the individual sites can be attributed to new canals being dredged within the sites. While there appears to have been some increase in land-to-water ratios at three sites, the improvements are not statistically significant and probably represent noise, rather

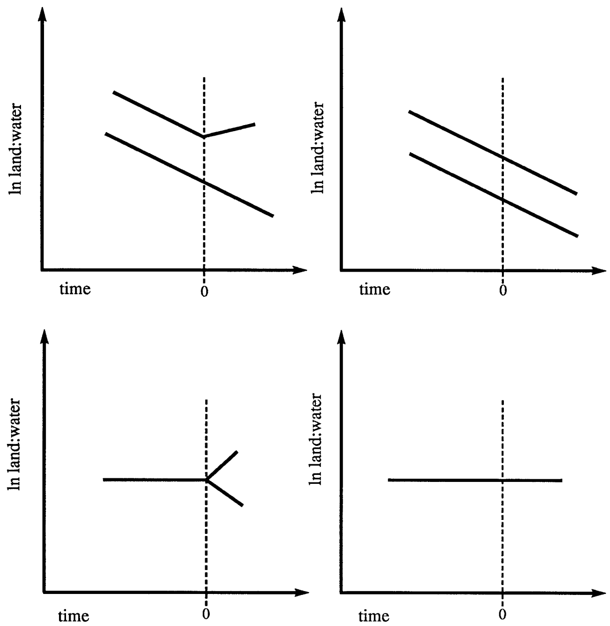

Figure 2. Diagrammatic change point models used in the statistical analyses performed on the land-to-water ratios. The point of management is 0 for all sites. The top models represent the full model (two variables). The bottom models represent the reduced model (one variable). The right-hand models represent the respective null hypotheses.

than a significant change in direction of the land-to-water ratios. Further, the improvements in ratios experienced by the three sites in this study may be attributed to a number of factors other than actual change in land-to-water ratios. These factors include: seasonal variance in water levels during photography; determination of land/water category in the new site photographs, or, simply the margin of error. These factors may have resulted in an indication of an increased land-to-water ratio where no increase actually occurred. No clear distinction can be made between active or passive management types. Both types in this study have sites that showed some increase in land-to-water ratios. Additionally, managed sites that showed increased ratios represent both fresh and brackish, deltaic and chenier plains—no further distinction can be drawn from these data.

Results from Statistical Analyses

The result of the first statistical model analysis was that the null hypothesis was not rejected ($P = 0.16$). The results from the second statistical model also indicated that the null hypothesis would not be rejected ($P = 0.62$). In other words, for both analyses, a management effect on the land-to-water ratios was not detected when compared to the reference sites. The results of these two analyses indicate that: (1) management is not having a significant positive effect of land-to-water ratios, and (2) trends or changes in the land-to-water ratios are not a consequence of management activities.

Discussion

Marsh management in coastal Louisiana consists of numerous small sites imbedded in a larger mosaic of dramatically altered coastal wetlands. Boumans and Day (1994) stated "managed areas when compared to unmanaged areas are largely uncoupled with the surrounding estuary." While this is true in the hydrologic setting (e.g., fisheries exclusion), the results of this study show otherwise in the larger scale. The larger environmental setting seems to have more influence on the managed sites than the management within. Can marsh management ever have a significant impact on land-loss? The management practices in Louisiana are trial and error—we clearly know less than we would hope and cannot predict with accuracy the outcome of our actions.

While this study demonstrates that marsh management through impoundment and water control does not have a significant impact on land-to-water ratios, it does not examine what happens to the surrounding marsh. As Turner and others (1994) have discovered, spoil banks (which amount to artificial levees) have a significant negative impact on marsh hydrology and, thereby, marsh health. Given the large quantity of artificial levees built in conjunction with marsh management through impoundments and water control, as studied in this paper, the surrounding marshes may be dramatically and negatively effected even though the area inside the levees may not be. The question then becomes, did the reference sites' land-to-water ratios decline in similar fashion to the managed sites in spite of management efforts or as a direct result of those efforts? All of the reference sites in this study were in close proximity to the managed sites. Would there be dramatic differences if the reference sites were selected in areas of "undisturbed" marsh? This question has implications for the policy of placing so much of Louisiana's coastal wetlands under this type of management.

This lack of accurate predictability has implications for the emerging practice of "mitigation banking." Mitigation banking is the practice of earning points or credits through marsh management activity in current sites. These points are deposited in a landowner's account for withdrawal against future mitigation-requiring activities (Wilkey and others 1994). It is also possible that these points could be used as a payment

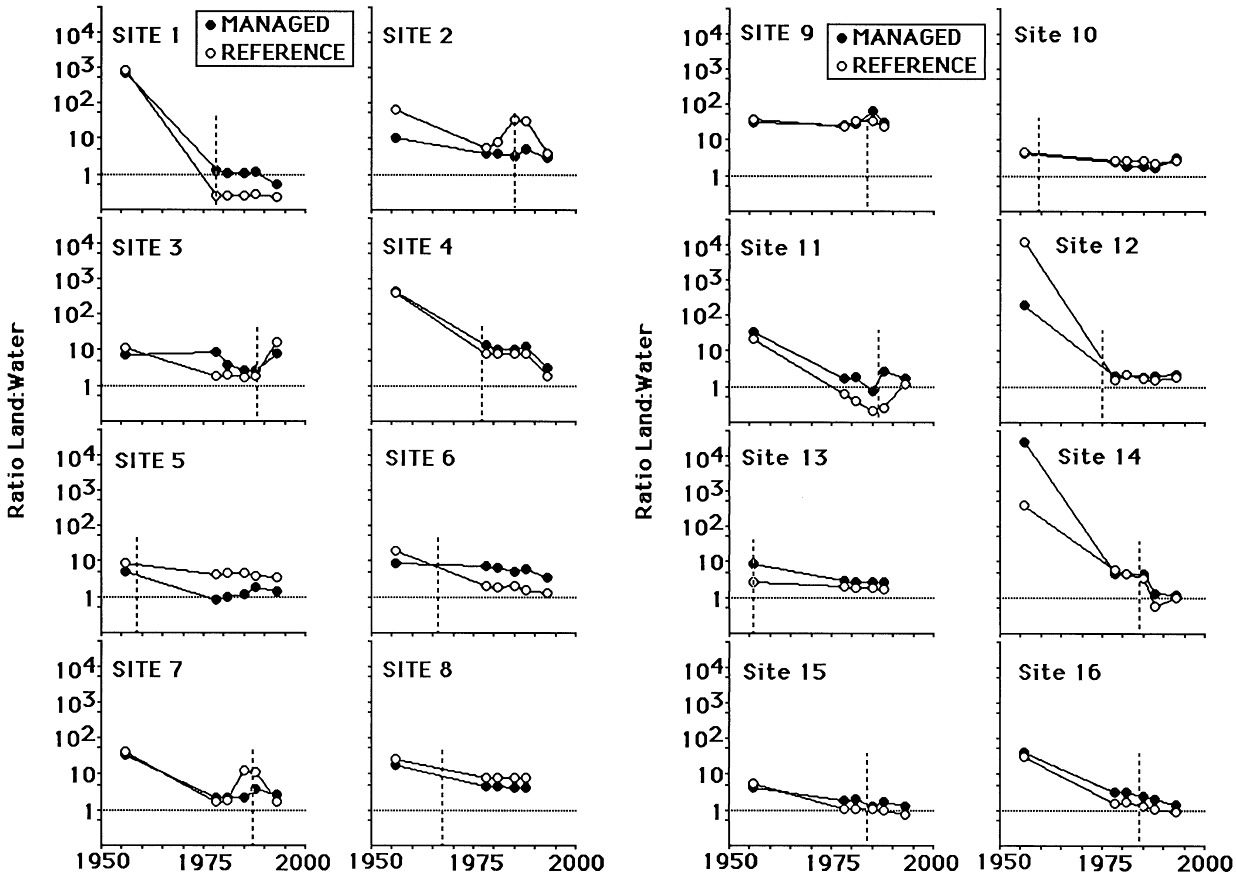

Figure 3. The land-to-water ratio versus year for the 16 sites. These plots are of raw land-to-water ratios, not the statistical analyses outputs mentioned in the text. The dashed line indicates the year of management intervention at the managed site.

against debits for development of a different site, or bought and sold among landowners (Wilkey and others 1994). No real benefits of increased wetlands or slowing/halting wetland losses may result at the management site, although benefits are assumed conceptually. If account holders claim their credits against future projects, a double deficit may occur where equal balance is assumed. That is, points may have been earned from management activity although that activity did not create any wetlands, and then those unearned points would be spent to destroy other wetlands. Additionally, points that were earned from questionably successful management techniques now, may be worthless when compared to new techniques of the future.

It appears that management of the type examined here has no measurable, much less a dramatic, effect in these marshes. There were no significant gains over many years of management. However, the management costs associated with current publicly funded coastal restoration efforts range from $1000/ha to $500,000/ha in Louisiana (Turner and others 1994). These estimates are for the anticipated benefits from several types of management, including marsh management. The assumption is that benefits will accumulate, whereas they may not, if the management is similar to what is used at the sites discussed in this analysis. Although the current rate of land-loss compels action to be taken, other types of action should be considered given the apparent lack of success in reversing or even retarding land-loss through marsh management. One such action that has shown demonstrated success is constructed crevasses, or intentional breaks in the natural river levee. Constructed crevasses build land at a very economical price (<$300/ha; Boyer and others 1995). Another is the deconstruction of spoil banks (Turner and others 1994; Trepagnier and others 1995).

Further studies, or an extension of this study over time, will help improve our understanding of the affects of marsh management in coastal Louisiana. However, this type of structural management does not appear to contribute to a reduction in land-loss rates. The concept of long-term benefits to the natural functions that the public benefits from (fisheries, wildlife and plant habitat) seems unproven. However, the individual landowner may have additional concerns (e.g., property rights and the direct or indirect increase in the efficiency of animal harvests) that may have been successfully addressed by marsh management.

Appendix: Individual Site Descriptions and Changes

Amoco West Black Lake

The managed and reference sites are located next to each other south of the Intracoastal Waterway west of Black Lake in the Calcasieu basin (site 1, Figure 1). Oil-field canals border both sites on the east. The primary management goal is to control or reverse land loss using nine flap-gated structures and variable-crest weirs, and pumps. Management began in 1987. Changes in the land-to-water ratios at the managed and reference sites mirrored each other. The overall trend was for lower land-to-water ratios over time (Figure 3).

Creole Canal

The managed site is located in the southwest portion of the Mermentau basin between two Chenier ridges (site 2, Figure 1). The area is bounded by Front Ridge Road on the north, Creole Canal to the east, and parts of the Mermentau River and an unnamed road to the south. The reference site is 8 km to the east and bounded by Hog Bayou on the south, a canal spoil bank on the east, Louisiana highway 82 on the north, and an unnamed road to the west. Management began in 1985, and uses four flap-gated, variable-crest weirs and an open culvert. Its goals are to actively reduce land-loss and increase wildlife habitat. Managed and reference site land-to-water ratios had similar trends, with the exception of an increase in the reference site over two sampling periods in the early 1980s (Figure 3).

Little Pecan Unit 6

Both managed and reference sites are bordered by the Little Pecan Bayou on the north, and by oil exploration canals on the southeast and west, 6 km south of Grand Lake and 6 km east of the Mermentau River (site 3, Figure 1). The management objectives of controlling land-loss and enhancing wildlife habitat is attempted using one flap-gated, variable-crested culvert and one variable-crest weir. Management began in 1978. The managed and reference sites show similar trends in land-to-water ratios, with both sites experiencing an increase in land-to-water ratios during the latest sampling period. However, that increase was much higher in the reference site than in the managed site (Figure 3).

Little Pecan Unit 9

The managed and reference sites are next to each other 2 km south of Grand Lake (site 4, Figure 1). Canals and trenasses (ditches used by fur trappers) form the boundaries of the managed site, and artificial waterbodies and their spoil banks define the reference site—except for the southern boundary, which is open marsh. The primary management goals are to enhance wildlife habitat and control land-loss. Management commenced in 1977 and uses two flap-gated culverts. The land-to-water ratios in managed and reference sites are nearly identical, with an overall decline (Figure 3).

Rockefeller Refuge

The managed area is located in the Mermentau Basin and is bordered on all sides by canals (site 5, Figure 1). The reference site is 15 km east of the managed site. Improving habitat is the primary management objective. The management plan uses two flap-gated, variable-crest weirs. Management began in 1958. Both managed and reference sites exhibited an overall decline in land-to-water ratios. However, the managed site exhibited a slight increase in the land-to-water ratio from the late 1970s to the present (Figure 3).

Vermilion Corporation

Located in the Mermentau basin, the managed site is next to Freshwater Bayou Canal (site 6, Figure 1). The spoil levees of man-made canals define the southern and eastern boundaries. The reference site is 1 km to the east and is completely surrounded by canals. A double flap-gated culvert is used to control land-loss and enhance wildlife habitat. Management began in 1966. The trend in land-to-water ratios for both managed and reference sites are similar and show an overall decline (Figure 3).

Vermilion Bay Land

The managed and reference sites are located next to each other in the Vermilion-Teche Basin (site 7, Figure 1), on the northern bank of the Gulf Intracoastal Waterway. The area is defined by Deer Bayou, Landry Canal, and the Gulf Intracoastal Waterway. The management goals are to enhance waterfowl and fur-bearer habitat as well as to reduce land-loss. Management began in 1987 and includes a flap-gated, variable-crest water control structure. Three other structures augment this active structure. The land-to-water ratios for both sites exhibit differing amounts of change in different directions (Figure 3). It should be noted that the mid- to late 1980s data points for the reference site were thought to be suspect by Sweeney and others (1990) because of climatic factors that might have temporarily affected water levels in the photographs used for his analysis.

Marsh Island Refuge

Marsh Island is located on the extreme western edge of the Delta Plain, below Vermilion Bay, and also within the Vermilion-Teche Basin (site 10, Figure 1). Both the managed and reference sites are next to each other. Site boundaries consist entirely of unnamed oil exploration canals. The passive management objective is to enhance waterfowl and fur-bearer habitat through the use of one fixed-crest weir. Management began in 1959. The land-to-water ratios at the managed and reference site were similar over the entire study (Figure 3). Marsh Island was one of the three sites that showed an increase in the last sampling period. However, the managed site did show a higher increase than in the reference site.

Avoca Bayou Lawrence

Both the managed and reference sites are located next to each other east of the Atchafalaya River below Morgan City in the Terrebonne Basin (site 11, Figure 1). The areas are bound in part by Glen Orange Canal, unnamed canals, and an open border with Avoca Lake. Management began in 1987 and has the goals of controlling land-loss and erosion and enhancing waterfowl habitat. The active management plan uses two variable-crest weirs and one double flap-gated culvert to control water levels. The land-to-water ratios in both managed and reference sites show somewhat similar trends (Figure 3), with the reference site showing a continued increase over three sampling periods.

Fina Falgout/Fina La Terre

The managed and two reference sites are next to each other, west of Bayou du Large in the Terrebonne Basin (site 12, Figure 1). The two reference sites were dot counted separately and the counts totaled to represent one site. Site boundaries include Marmande Ridge, Minors Canal, Thibodeaux Canal, and Falgout Canal. Active management uses four fixed-crest weirs, and a flap-gated, variable-crest weir to decrease or reverse land-loss and control or reduce salinity. Fina La Terre is a mitigation bank site (discussed earlier), and management commenced in 1985. The land-to-water ratios are very similar for both managed and reference sites (Figure 3). This site was one of the three that had an increase in ratios for the latest sampling period. The ratio in the reference site increased more than in the managed site.

Fina Bayou Chauvin

Both managed and reference sites are in the lower Bayou Chauvin watershed above Lake Boudreaux (site 14, Figure 1). The inactive distributaries of the Mississippi River, Bayou Grand Caillou, and Bayou Petite Caillou define the site boundaries. Passive management uses two fixed-crest weirs to stabilize land-loss and began in 1984. The trends in land-to-water ratios are generally similar for both managed and reference sites (Figure 3), with each having an increased ratio for one sampling period.

L. H. Ryan

The L. H. Ryan study areas are located in the Barataria basin (site 15, Figure 1) and are comprised of several small managed and reference sites. All managed and reference sites are bordered by oil exploration canals. Management goals of land-loss control and habitat enhancement are carried out using two variable-crest weirs with flap gates. Management began in 1986. The trends in land-to-water ratios show a decline and are generally the same for both managed and reference sites (Figure 3).

Lafourche Realty Company

Both managed and reference sites are next to each other in the Barataria Basin south of Yankee Canal and east of Golden Meadow (site 16, Figure 1). The site borders include oil exploration canals, spoil banks, and Bayou Lafourche. Passive management commenced in 1984 and includes four culverts and two slotted fixed-crest weirs to achieve plan goals of controlling land-loss and enhancing waterfowl and fur-bearer habitats. The trend in land-to-water ratios for both managed and reference sites are virtually the same and exhibit an overall decline (Figure 3).

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