Palustrine System

Palustrine Emergent Wetlands

Palustrine emergent wetlands (PEM), or "inland," "fresh-water" marshes, cover more than 22,000 acres (figs. 23 and 25), and represent approximately 16 percent of the vegetated wetland system (including aquatic beds), and 17 percent of the marsh (emergent wetland) system. The widest distribution of this habitat occurs in inland areas along the Trinity River alluvial valley in the Anahuac and Cove quads, inland of Christmas Bay and West Bay (Oyster Creek and Hoskins Mound quads), and inland of East Bay (Frozen Point and High Island quads) (figs. 2 and 25). Cove, Oyster Creek, and Anahuac have the largest areas of palustrine emergent wetlands, accounting for about 4,380, 3,600, and 3,360 acres, respectively (fig. 27). Frozen Point has almost 3,000 acres, and Hoskins Mound and High Island each contain more than 1,000 acres (fig. 27).

Palustrine Scrub-Shrub Wetlands

Palustrine scrub-shrub wetlands (PSS) total about 2,000 acres (fig. 23) (slightly >1 percent of vegetated wetlands); much of this acreage occurs in the Highlands (422 acres) and Dickinson quads (300 acres). All other quads each contain less than 140 acres of scrub-shrub wetlands. Most areas of scrub-shrub occur along rivers, bayous, and creeks, on the margins of reservoirs, and in relatively small depressions.

Palustrine Forested Wetlands

The total area of forested wetland habitat amounts to 5,648 acres (fig. 23), or about 4 percent of the vegetated wetland system (including aquatic beds). Forested wetlands (PFO) are most abundant in the Trinity River floodplain, defined by the Anahuac and Cove quads; these quads contain about 2,320 and 1,890 acres of forested wetlands, respectively. Other quads with notable acreages of PFO are Oyster Creek (675 acres), Highlands (441 acres), and Hitchcock (141 acres). The distribution of forested wetlands in other quads range from 55 to 0 acres.

TRENDS IN WETLAND HABITATS

Methods Used to Analyze Trends

Trends in wetland habitats were determined by analyzing habitat distribution as mapped on 1950's (fig. 30), 1979 (fig. 31), and 1987–1989 (fig. 24) aerial photographs. Most of the analyses focused on changes that occurred between the 1950's and late 1980's, the longest period of record. In analyzing trends, emphasis was placed on wetland classes (for example, E2EM and PEM), with less emphasis on water regimes and special modifiers. This approach was taken because habitats were mapped only down to class level on 1950's photographs and because water regimes can be influenced by local and short-term events such as tidal cycles. The 1979 photographs were taken during a period of high tides and the 1989 photographs during a period of low tides.

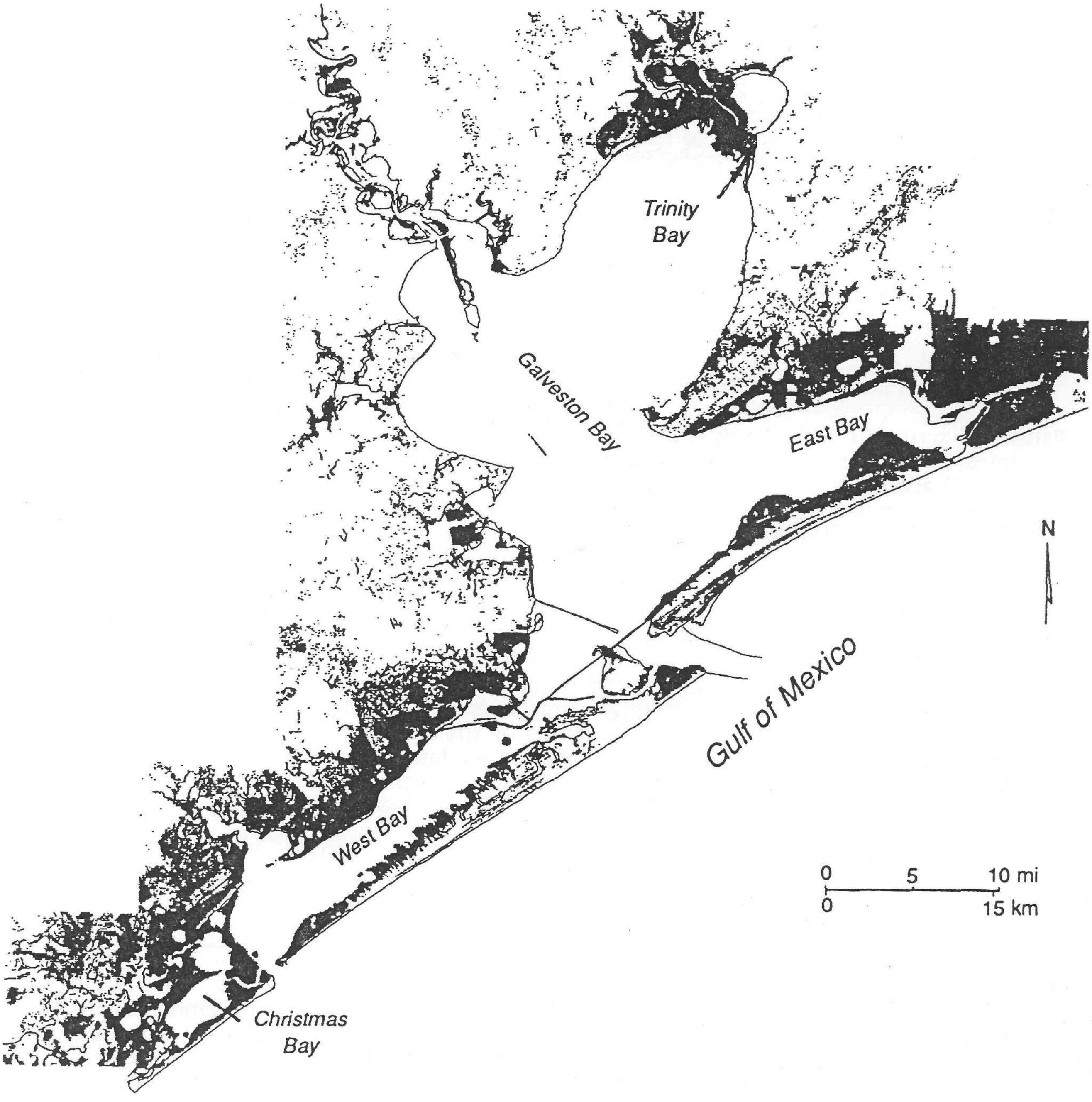

Figure 30. Distribution in the 1950's of estuarine (E2EM and E2EM/FL) and palustrine (PEM) emergent wetlands (marshes) in the Galveston Bay system.

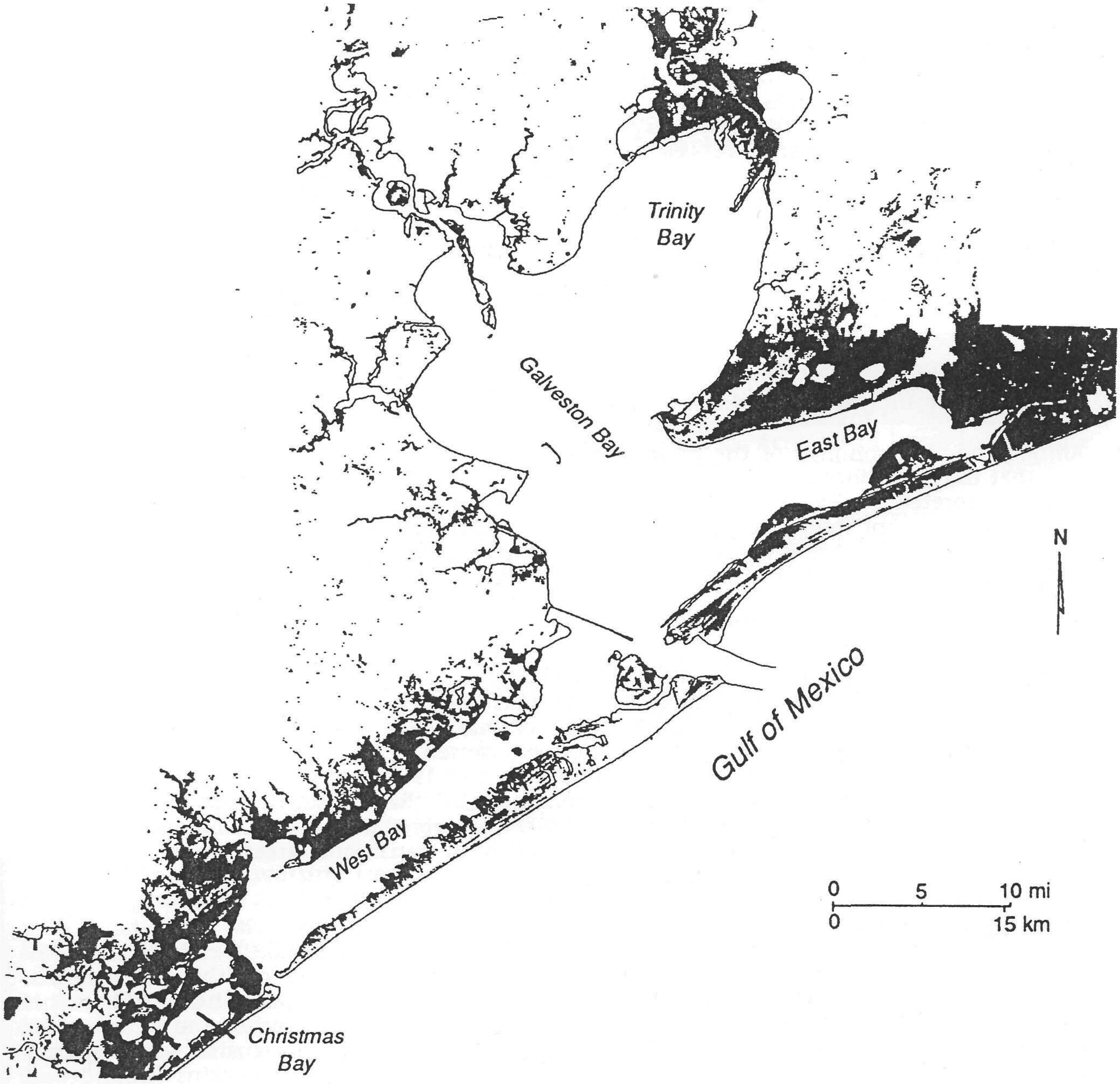

Figure 31. Distribution in 1979 of estuarine (E2EM and E2EM/FL) and palustrine (PEM) emergent wetlands (marshes) in the Galveston Bay system.

Geographic Information System

The geographic information system, ARC/INFO, was the primary tool used in analyzing trends. It allowed for direct comparison between years, generally on a quad by quad basis. Analyses included tabulation of losses and gains in wetland classes for each quad for selected periods. In addition, full-color, 1:24,000-scale maps showing basic wetland classes as mapped on 1989 photographs were prepared for each quad. These maps allowed relatively clear visual comparisons of changes to be made on a light table by overlaying them with the blue-line prints of the 1950's and 1979 map series. Supplementary to these maps were full-scale (1:24,000) colored maps showing vegetated-wetland losses and gains for the 1950's to 1989 period for each of the 30 quads. The GIS allowed cross classification of habitats in a given area as a means of determining changes and probable cause of such changes. Maps used in this report showing wetland distribution and changes were prepared from digital data using ARC/INFO.

Possible Photointerpretation Errors

Among the shortcomings of the photointerpretation process for this project (aside from the fact that different photointerpreters were involved for different time periods) is that wetlands were interpreted on each set of photographs without reference to the photographs taken during preceding or following years (this was particularly true for the 1950's and 1979 series). This procedure, in part unavoidable, prevented photointerpreters from selecting the most consistent (and accurate) wetland boundaries, especially along wetland-upland breaks, for the different time periods. As a result, some changes in the distribution of wetlands from one period to the next are not real but are relicts of the interpretation process.

The most striking example occurred in the Lake Stephenson quad inland from East Bay where an apparent gain of more than 3,500 acres of marshland between the 1950's and 1979, was offset by an almost equal loss (>3,000 acres) of marshland between 1979 and 1989. The apparent gain during the 1950's to 1979 period was caused by the inclusion of upland habitats within the irregularly flooded wetland habitat on the 1979 maps. The complexity of this particular area, characterized by upland "pimple mounds" that are surrounded by topographic lows marked by wetter conditions, complicated the interpretation process. Inconsistencies in interpretation seem to have occurred most frequently in transitional areas similar to this one where uplands and wetlands intergrade.

Some apparent wetland changes were due to the different scales of the aerial photographs. The 1950's aerial photographs were at a larger scale (1:24,000) than those taken in 1979 and 1989 (1:62,500), which affected the minimum mapping unit delineated on the photographs. Accordingly, more wetlands were mapped on the earlier, larger-scale photographs. This effectively produced a larger wetland loss (an apparent loss) between earlier and later periods than occurred. Such apparent losses were most pronounced in interior (palustrine) wetlands where complex distribution patterns were common, such as in the Hoskins Mound and Hitchcock quads.

The 1950's photographs were reviewed for three quads to estimate the extent of interpretation errors. Minor problems (excluding the scale problem mentioned above) in interpretation (consistency and accuracy) were found in the Lake Stephenson quad. In the Hoskins Mound area, some uplands that were peripheral to wetlands were misclassified as wetlands due to local high water at the time the photographs were taken. The third quad (Christmas Point) contained more extensive misclassifications. For example, some densely vegetated marshes (E2EM areas) were classified as mixtures of marshes and flats (E2EM/FL). A more significant misinterpretation in this quad, however, was the delineation of upland areas as estuarine emergent wetlands, which inflated the 1950's wetland totals. As a result, comparison of the 1950's totals with totals in later years reflects a larger loss in emergent wetlands than actually occurred. In fact, in this quad (Christmas Point) it appears that approximately 40 percent (almost 900 acres) of the reported losses in estuarine emergent wetlands for the period 1952–1953 to 1989 was due to interpretation errors rather than to real changes. In the Hoskins Mound quad it was estimated that about 40 percent of the wetland changes were also related to photointerpretation, in large part the result of photographic scale differences and very wet conditions in the early 1950's.

Based on the selected reviews of interpretations (supported by expected trends), it appears that the 1950's Christmas Point and Hoskins Mound examples and the 1979 Lake Stephenson example are extreme cases due to the complexities of the wetland distribution patterns in these quads. Considering the bay system as a whole, it is believed that the amount of change in wetland distribution attributable to misinterpretation is much lower than the above 40-percent examples; it should be less than 20 percent. Ideally, wetland habitats should be delineated with reference to all vintages of photographs to promote consistency and accuracy in the delineations. This could not be accomplished in this investigation without redoing the 1950's and 1979 maps.

In general, losses that seem to have been influenced most by photointerpretation problems are interior (palustrine) temporarily flooded wetlands with complex distribution patterns that appear to have been overestimated on the 1950's photographs and perhaps underestimated on the 1989 photographs for reasons noted in the above discussion. Acreages of losses in estuarine emergent wetlands are supported in many areas by previous studies and appear more reliable.

In the analysis of trends, wetland areas for the different time periods are compared without attempting to factor out misinterpretations and photo-to-map transfer errors. However, maps representing each period were visually compared for the 30 quads as part of the trend-analysis process and as part of the effort to identify potential problems in interpretation. Aerial photographs were spot checked as part of this review. Occasional comments in the text with respect to apparent changes are based on these comparisons, as well as on prior knowledge of wetland distribution in the Galveston Bay system (White and others, 1985). Still, users of the data should keep in mind that there is a margin of error inherent in photointerpretation and map preparation.

Trends in Wetland Distribution

In analyzing and discussing trends, emphasis is placed on net losses in wetlands. Typically within a quad there are spatial changes in the distribution of a given wetland class manifested by losses in one area that are partly or wholly offset by gains in other areas of the quad. Determining the difference between the losses and gains yields the net change.

In general terms, losses in vegetated wetlands may result from conversion of the wetlands to (1) open water and flats, (2) uplands, or (3) other wetland classes. Reasons for such transformations are analyzed and discussed in a later section on probable causes of wetland losses.

Trends: 1950's to 1989

Comparison of wetland distribution in the Galveston Bay system for the 1950's and 1989 indicates that there were gains and losses in wetlands over this period, but the net trend is one in which wetlands were lost (fig. 32). The area of vegetated wetlands (E2EM, E2SS, PEM, PSS, and PFO) decreased from approximately 171,000 acres in the 1950's to about 138,600 acres in 1989 (fig. 33). This loss of 32,400 acres amounts to 19 percent of the vegetated wetland system that existed in the 1950's. The actual loss in wetlands is somewhat less, perhaps closer to 17 percent, because delineations of wetlands in some areas on the 1950's-vintage black-and-

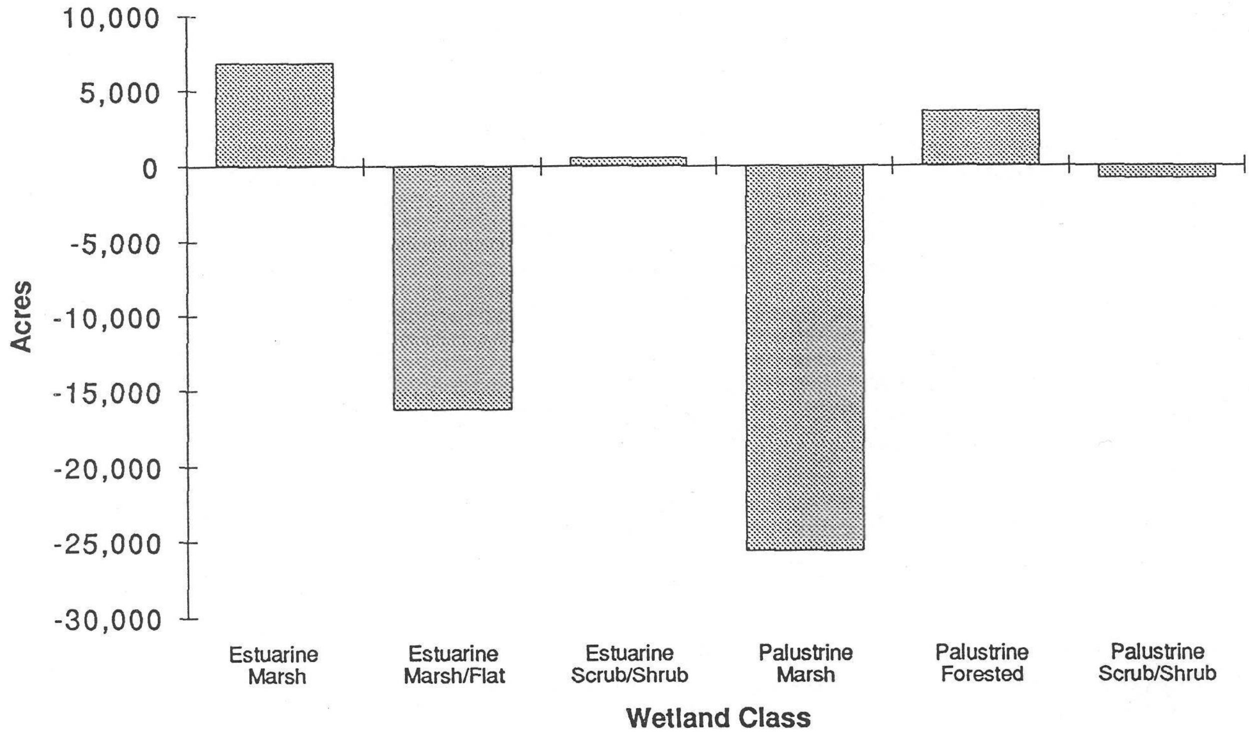

Figure 32. Net losses and gains in vegetated wetland classes (excluding aquatic beds) from the 1950's to 1989. The apparent increase in emergent wetlands (E2EM) is in large part due to reclassification of PEM and E2EM/FL (E2EM/US) areas in the 1950's to E2EM areas in 1989 (and 1979).

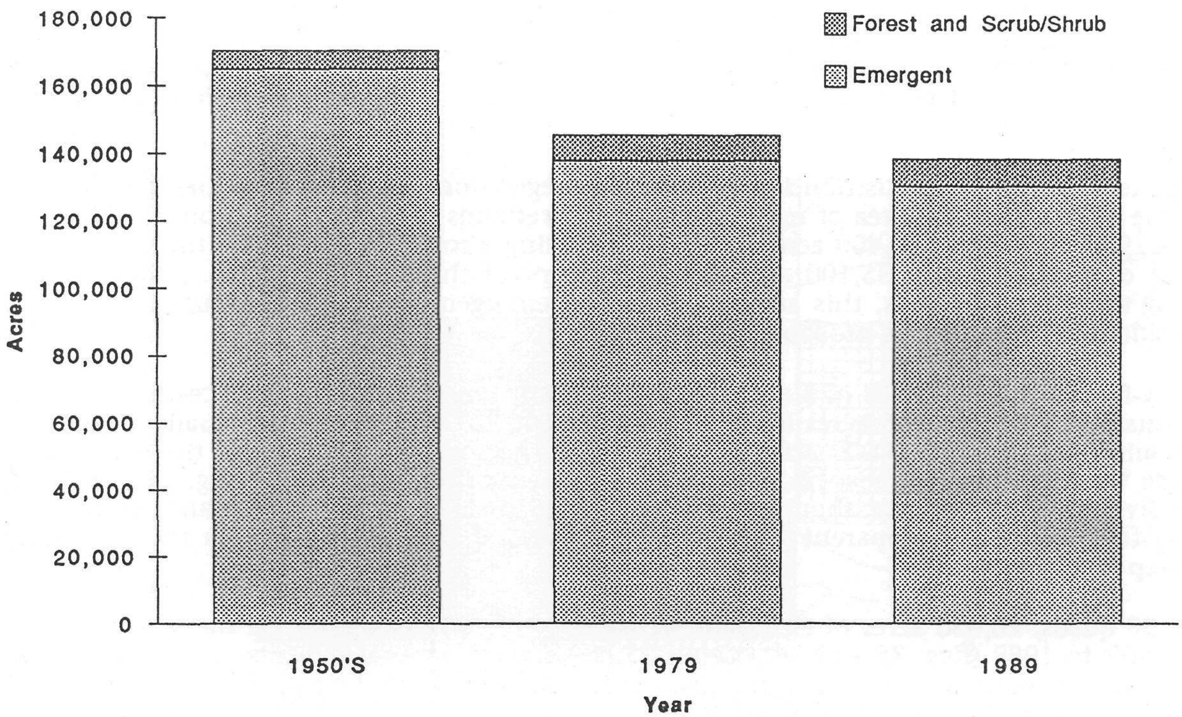

Figure 33. Bar graph comparing areas of emergent and forest/scrub-shrub wetlands for the 1950's, 1979, and 1989.

white aerial photographs included peripheral upland areas, which inflated the 1950's wetland acreages (see previous section on possible photointerpretation errors).

Estuarine and Palustrine Emergent Wetlands

Estuarine (E2EM) and palustrine (PEM) emergent wetlands, which are fundamentally equivalent to salt/brackish and fresh marshes, are considered together as a marsh system for analysis purposes. In addition, undifferentiated areas of emergent wetlands and tidal flats (mapped as E2EM/FL on 1950's and 1979 photographs and E2EM/US and E2US/EM on the 1980's photographs) are included with emergent wetland areas rather than with tidal-flat areas. These combinations are made because of inconsistencies in mapping of these areas for the different time periods.

The general trend in the distribution of emergent vegetation (marshes) from the 1950's to 1989 was one of net loss. The area of mapped emergent wetlands decreased from about 165,500 acres in the 1950's to about 130,400 acres in 1989, producing a total net loss across the Galveston Bay system of approximately 35,100 acres, or 21 percent of the 1950's resource. Again, as in the case of vegetated wetlands, this amount of loss in emergent wetlands is thought to be on the high side; the actual loss is probably below 19 percent.

Twenty-five of the 30 quads had apparent net losses in vegetation. Losses exceeded 3,000 acres in 5 quads, 1,000 to 3,000 acres in 10 quads, and 500 to 1,000 acres in 2 quads (fig. 34). The most substantial losses (>3,000 acres) are located in the southwestern part of the map area and include Virginia Point, Hitchcock, Hoskins Mound, Texas City, and Sea Isle (fig. 34). Changes in these five areas account for about 55 percent of the losses in emergent wetlands in Galveston Bay system. Areas with apparent losses of between 1,000 and 3,000 acres are scattered around the map area (fig. 34).

In all 30 quads, 26,450 acres of emergent wetlands were converted to open water and flats from the 1950's to 1989 (figs. 35 and 36). About 35,800 acres of emergent wetlands became uplands, either through natural or artificial processes. Additional losses in emergent vegetation were due to changes in wetland class such as from emergent vegetation to scrub-shrub vegetation. The total gross "loss" in emergent vegetation exceeded 88,500 acres.

The most extensive net loss occurred in the Virginia Point quad located on the inland margin of West Bay, where more than 5,000 acres of emergent wetlands disappeared by 1989. The gross loss in emergent wetlands exceeded 8,000 acres, but this amount was offset by increases of about 3,000 acres in other areas of the quad. About 3,600 acres of emergent wetland habitat was converted to open water (E1UBL) and tidal flats (E2US) (figs. 35 and 36). Most of the remainder of the decline was due to a change from emergent wetlands to uplands.

In other quads where net losses in emergent wetlands exceeded 3,000 acres, three (Hitchcock, Hoskins Mound, and Texas City) were characterized principally by conversion of marshes to uplands; replacement of marshes by open water and intertidal flats was of secondary importance. In the fourth (Sea Isle), decreases in emergent wetlands were about equally distributed between conversions to open water/flat and to uplands. In Cove, Highlands, and Anahuac, transformation of vegetated wetlands to open water and flats accounted for more than 80 percent of the loss in emergent wetlands in these quads. For the remaining quads, conversion of emergent wetlands to uplands accounted for between 40 and 95 percent of the change, while conversion to open water and flats accounted for most of the remainder.

Losses in emergent wetlands in some areas were partly offset by gains in emergent wetlands in other areas. Much of the increase in wetlands occurred in areas previously mapped as uplands; this type of conversion, from upland to wetland, accounted for an increase of about 21,000 acres (figs. 37–39). Regionally, these changes were most pronounced inland from East Bay, for example in the Lake Stephenson quad (fig. 40), on Galveston Island (fig. 41), and

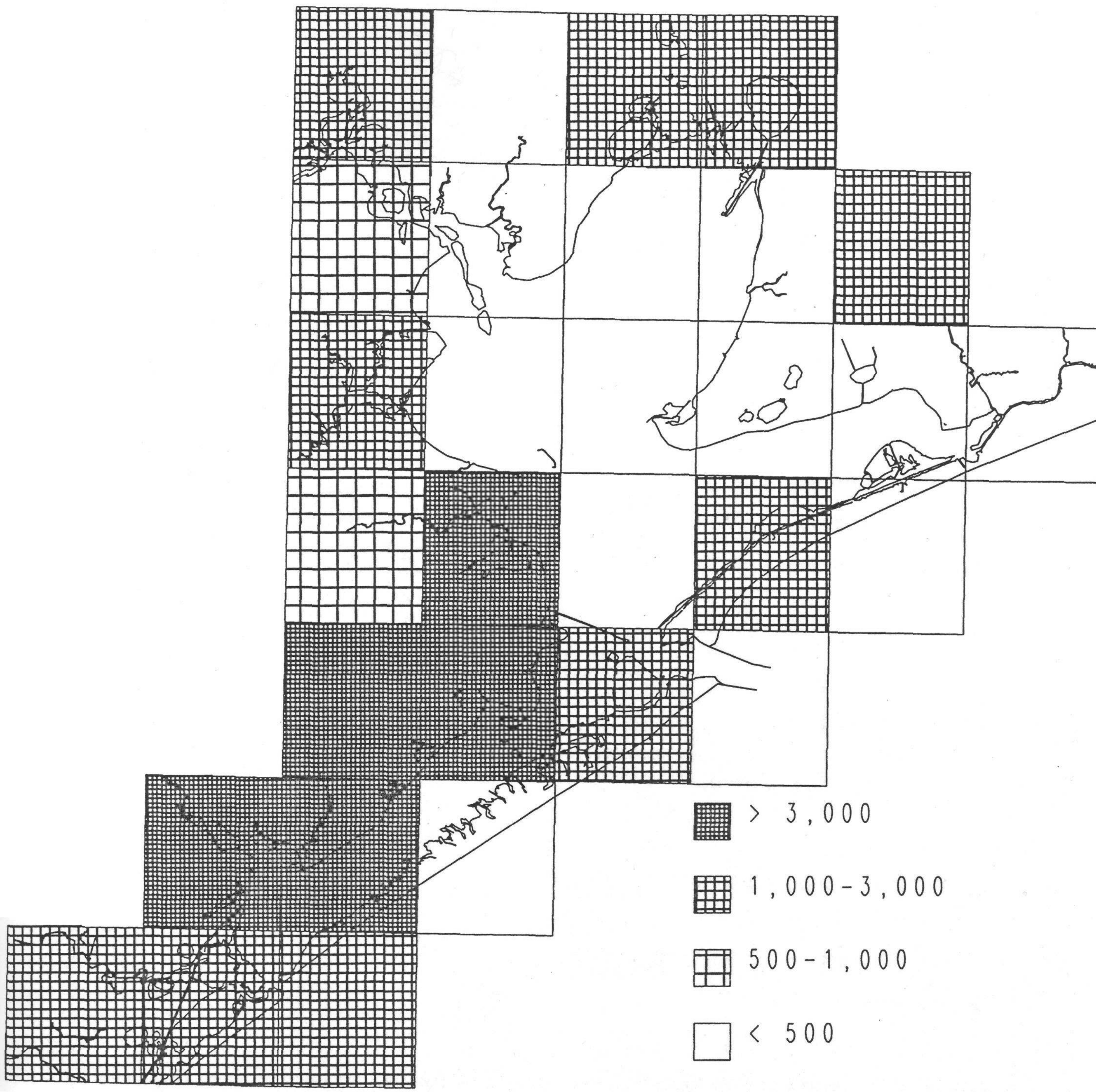

Figure 34. Map showing distribution of emergent wetland net losses (in acres), 1950's to 1989, for 7.5-minute quads defining the Galveston Bay study area.

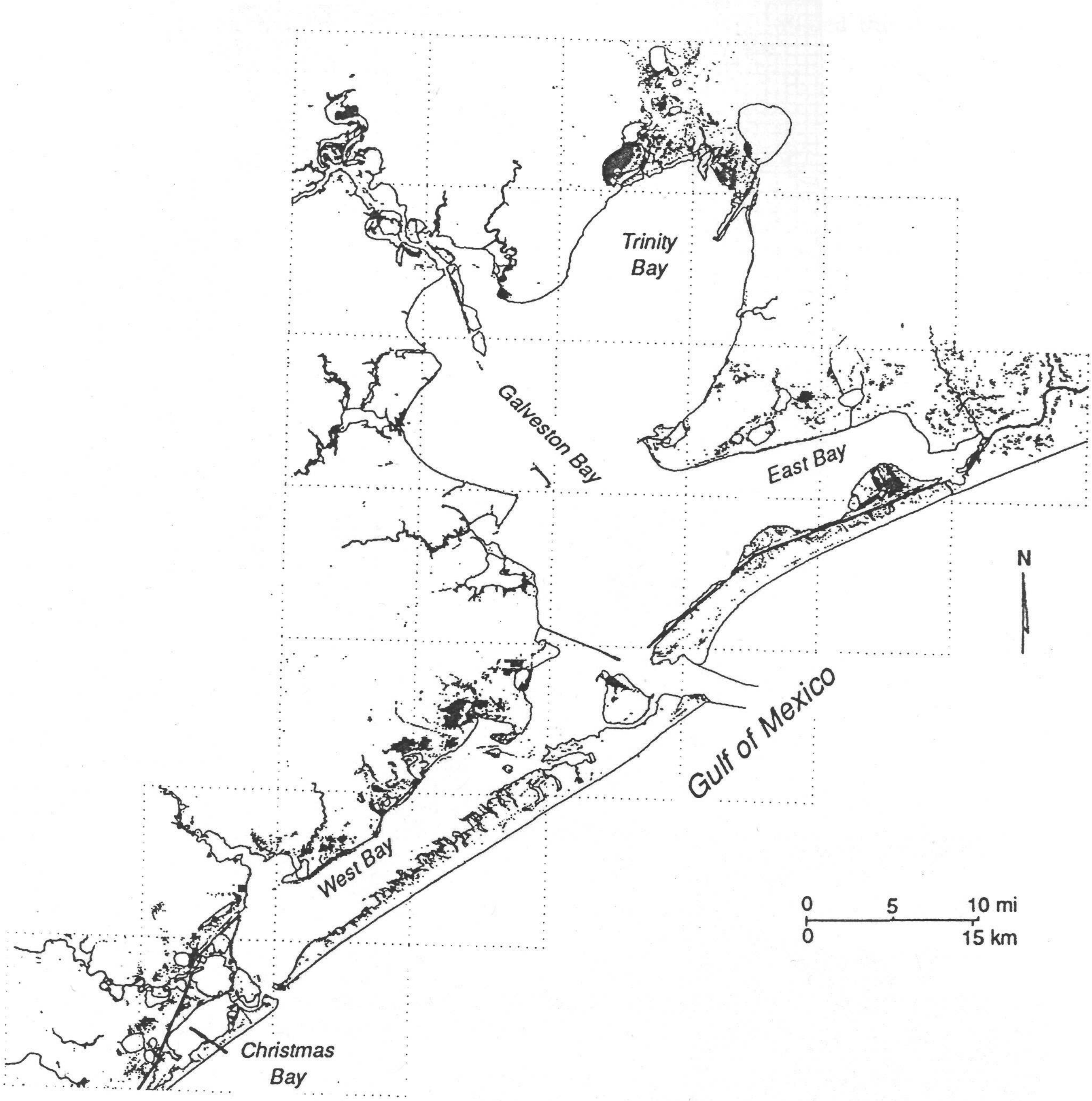

Figure 35. Distribution of emergent wetlands (marshes) (shaded areas) that were displaced by water and barren flats between the 1950's and 1989. Areas where losses were extensive include the Trinity River delta at the head of Trinty Bay (fig. 59), inland margin of West Bay (figs. 55 and 56), and fan-like feature on Bolivar Peninsula Gulfward of East Bay (figs. 52 and 60).

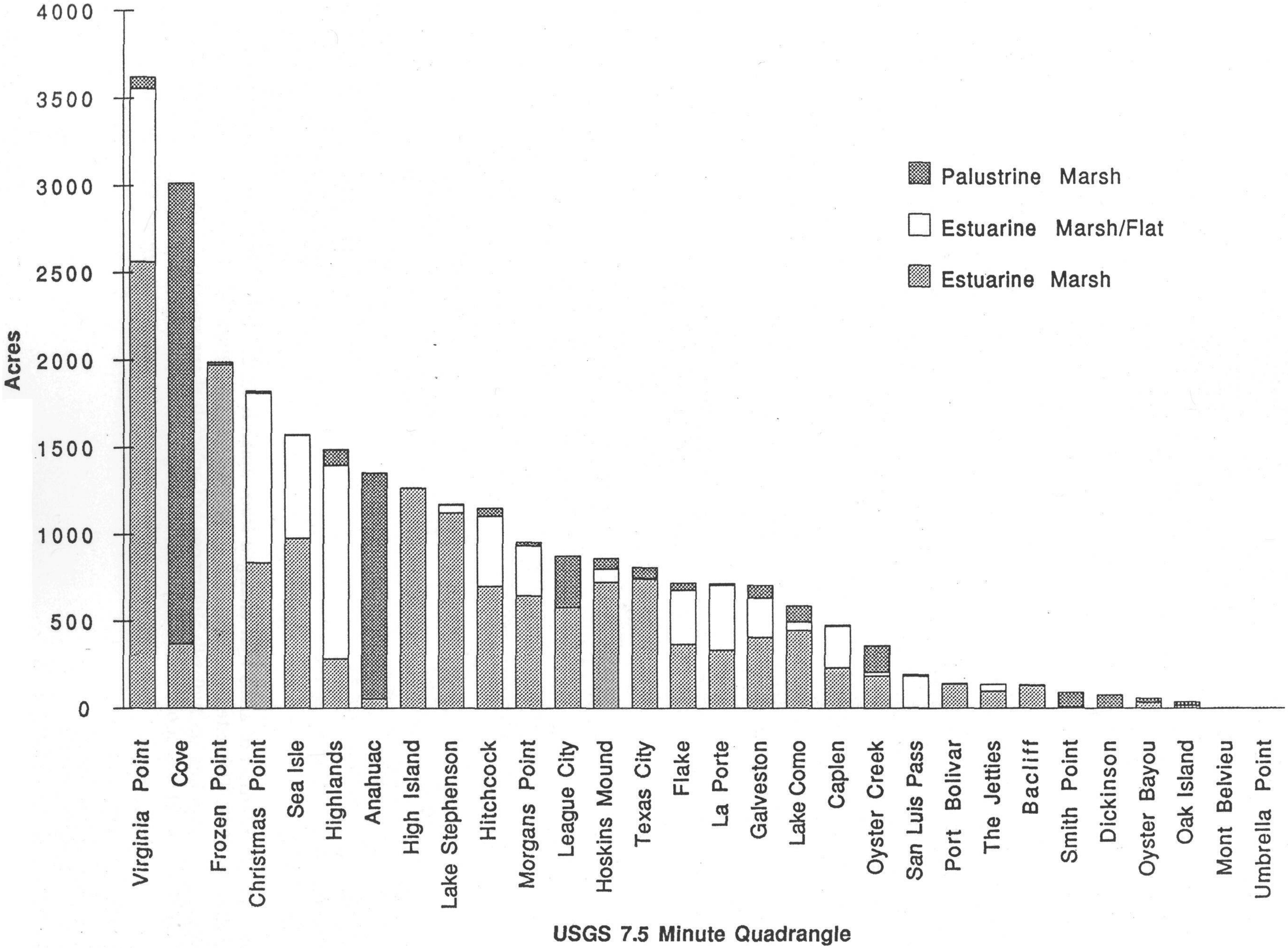

Figure 36. Bar graph showing the extent of losses in emergent wetlands (marshes) in each quad due to conversion to open water and barren flats, 1950's to 1989.

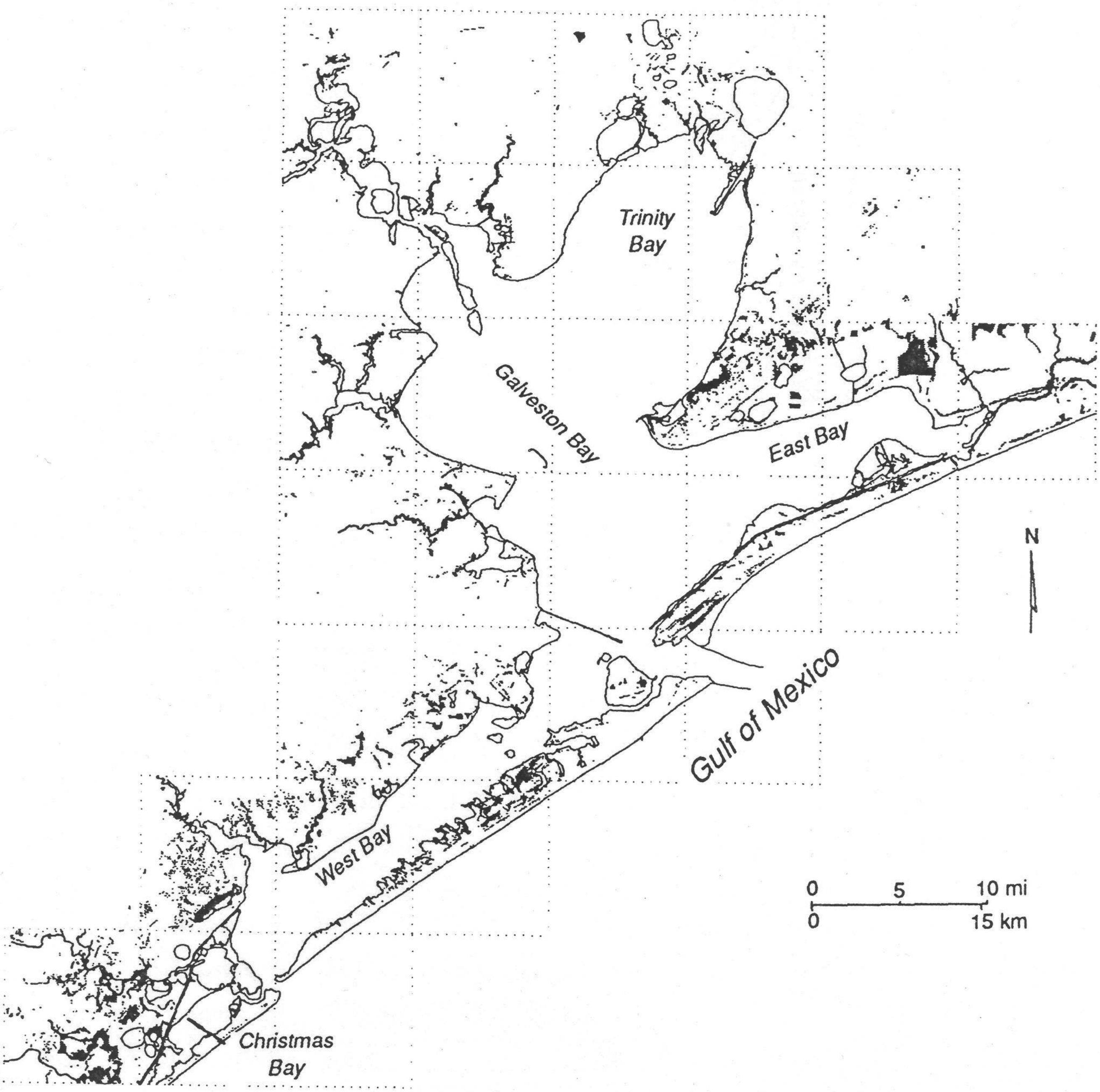

Figure 37. Distribution of areas that changed from uplands in the 1950's to emergent wetlands (marshes) in 1989. The extent of these changes are shown on figures 38 to 42.

Figure 38. Map of 7.5-minute quads showing the geographic distribution and extent (in acres) of areas that changed from uplands to emergent wetlands (marshes) from the 1950's to 1989. See figures 40 to 42 for more specific changes in quads.

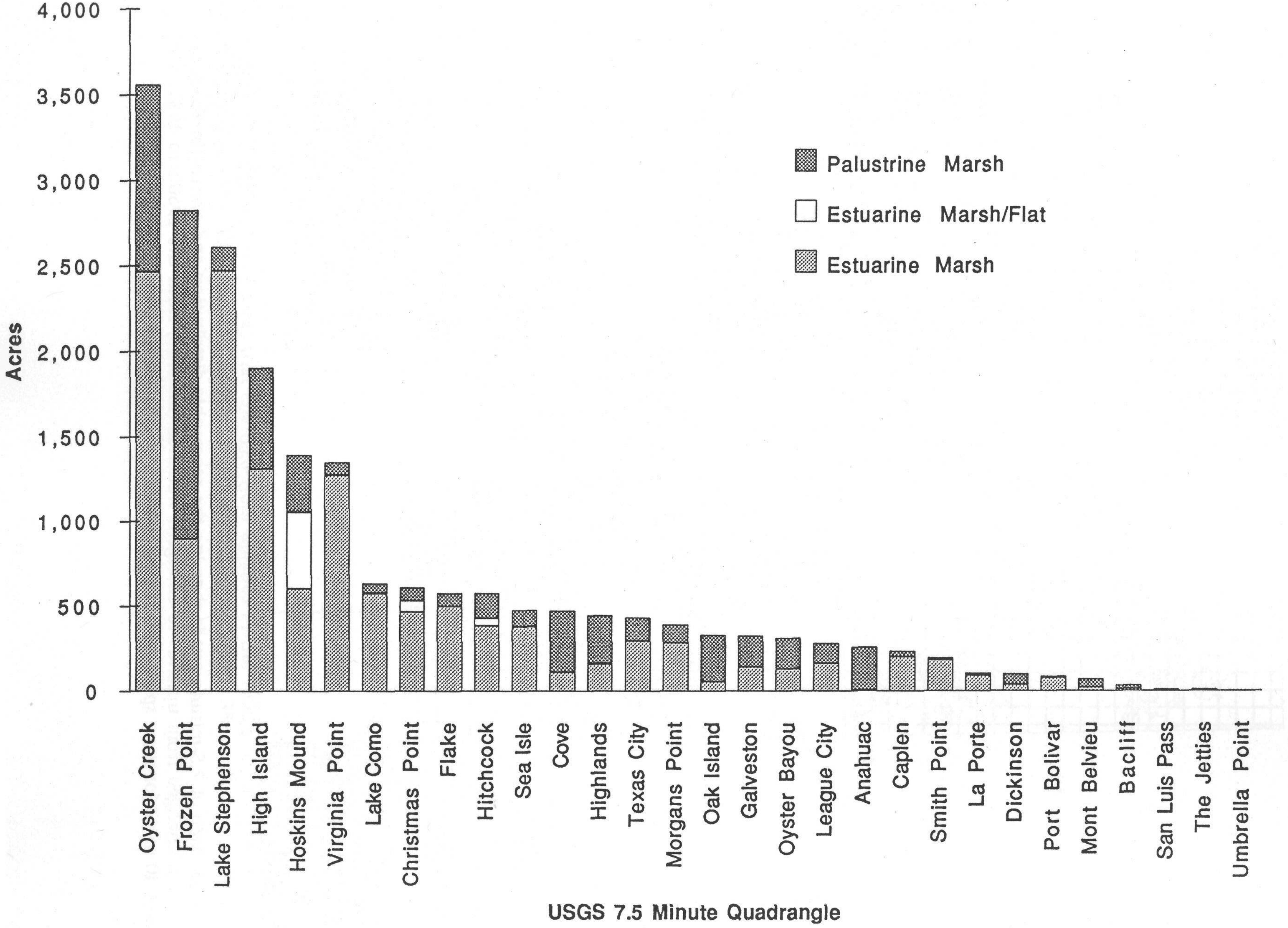

Figure 39. Bar graph of 7.5-minute quads showing extent (in acres) of areas that changed from uplands to emergent wetlands (marshes), 1950's to 1989.

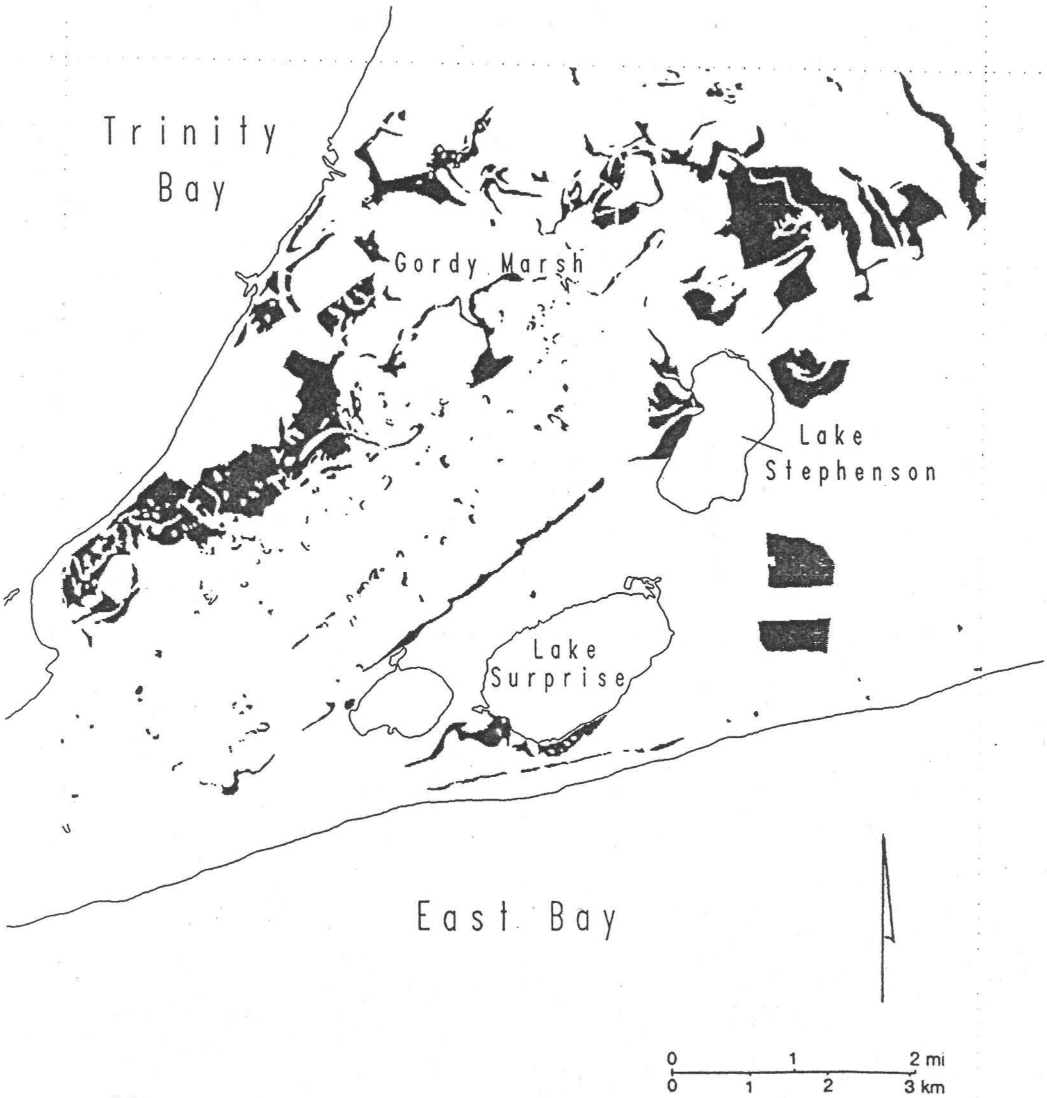

Figure 40. Distribution of areas (shaded) that changed from uplands (1950's) to emergent wetlands (1989) in the Lake Stephenson quad. Subsidence associated with the fault shown in figure 61 is suspected of having contributed to this change.

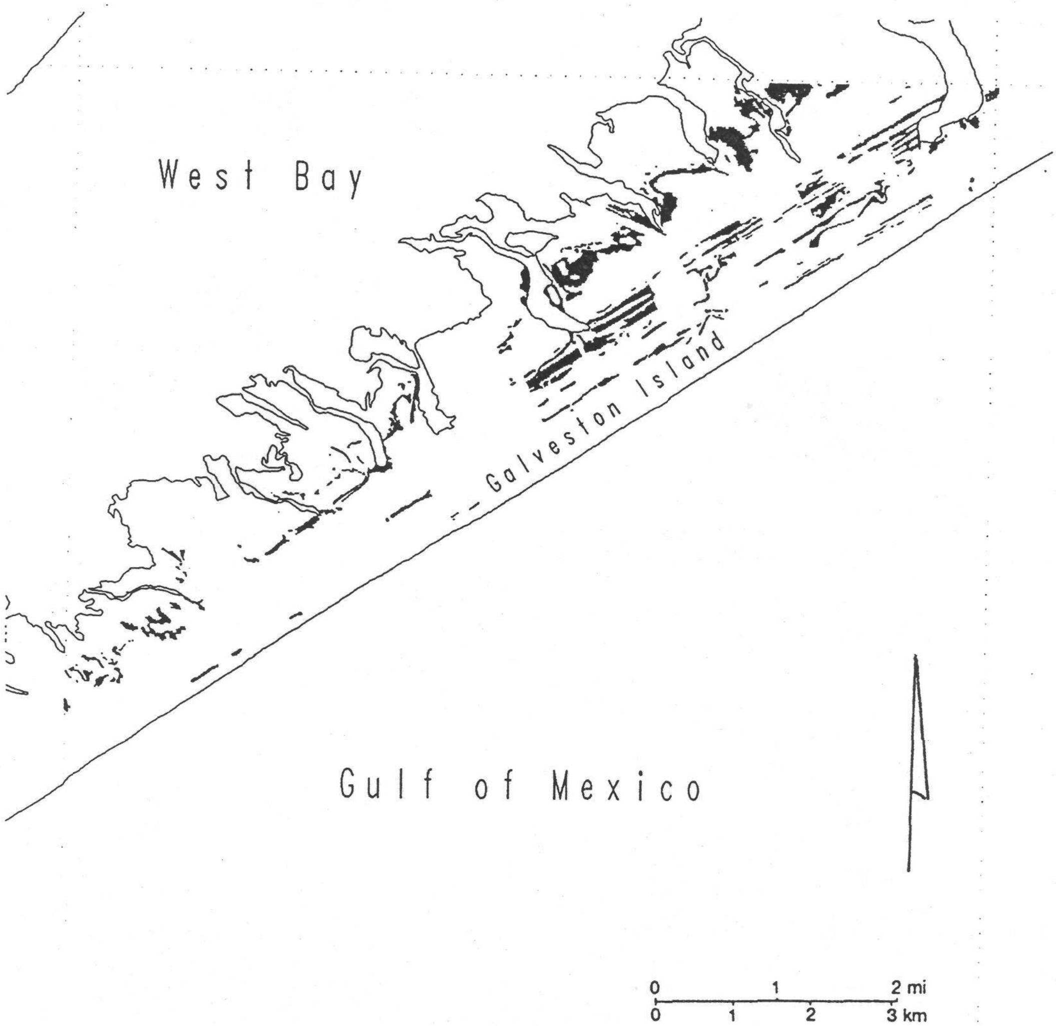

Figure 41. Distribution of areas (shaded) that changed from uplands (1950's) to emergent wetlands (1989) in the Lake Como quad. Linear features in the central part of Galveston Island are wetland increases in swales between relict beach ridges. Increases on the bayward side of the island is perhaps due to subsidence on Galveston Island reported by Zimmerman and others (1991).

inland from West Bay and Christmas Bay (Oyster Creek quad, fig. 42). The conversion of uplands to wetlands generally took place in transitional areas peripheral to existing wetlands. Additional increases in emergent wetlands resulted from the spread of emergent vegetation over areas previously mapped as intertidal flats. This type of change was confirmed by comparing aerial photographs. Such changes occurred on some intertidal sand flats on Galveston Island and Bolivar Peninsula. Still, the reverse of this type of change, the conversion of emergent wetlands to flats, was more extensive on these barrier islands.

Scrub-Shrub and Forested Wetlands

The general trend in scrub-shrub wetlands for the 1950's to 1989 period was one of net loss. This trend was countered by forested wetlands, which had a significant net gain. Scrub-shrub wetlands decreased by nearly 900 acres, representing a loss of about 25 percent of the 1950's resource. Forested wetlands, on the other hand, increased in area by approximately 3,600 acres, an increase of about 1.8 times the 1950's area (fig. 43).

For the 1950's, more than 90 percent of the mapped scrub-shrub habitat was contained in two quads centered on the Trinity River alluvial valley; the quads are Cove and Anahuac, which together account for more than 3,100 acres. The bulk of the loss in the scrub-shrub habitat between the 1950's and 1989 occurred in these two quads. Much of the loss (about 2,900 acres) in these two areas, however, was offset by gains in other quads. In fact, 22 quads had gains in scrub-shrub habitats (fig. 43).

The Cove and Anahuac quads are also important forested wetland sites, accounting for 84 percent of the 1950's forested wetland habitat, and 75 percent of the 1989 forested wetland habitat. The 3,600-acre increase in forested wetlands across the Galveston Bay system occurred primarily in these two quads, although there were apparent increases in forested wetlands in most quads where this habitat was mapped (fig. 43).

Estuarine Aquatic Beds

Submerged vascular vegetation (E1AB on 1950's maps and E1AB3L on 1989 maps) decreased from about 2,500 acres in the 1950's to approximately 700 acres in 1989. The acreage for 1989 was determined by subtracting 245 acres from the actual mapped total to delete misclassifications and inland aquatic beds. Using these acreages the decline in submerged vegetation is 1,800 acres, or more than 70 percent of the 1950's habitat. This may be an underestimate as discussed below and in the section on probable causes for losses.

The most extensive losses in submerged vegetation occurred in West Bay (fig. 28) (Lake Como, Sea Isle, and San Luis Pass quads), where the entire 1950's resource of almost 2,200 acres disappeared by 1989. Another area of loss occurred in western Galveston Bay near Clear Lake (fig. 28) (League City and La Porte quads), where at least 50 acres disappeared before 1989.

There is little doubt that a loss of submerged vegetation has occurred in the Galveston Bay system since the 1950's; losses have been reported by other studies (Pulich and White, 1991, for example). The magnitude of loss appears to be larger than the 1950's and 1989 map series reveal. For instance, approximately 5,000 acres of submerged vegetation were mapped in the Galveston Bay system by Fisher and others (1972) using 1956 aerial photographs. These photographs were taken during a drought when low water conditions and low turbidities possibly promoted both the maximum distribution of marine grasses (Pulich and White, 1991) and their interpretation on aerial photographs.

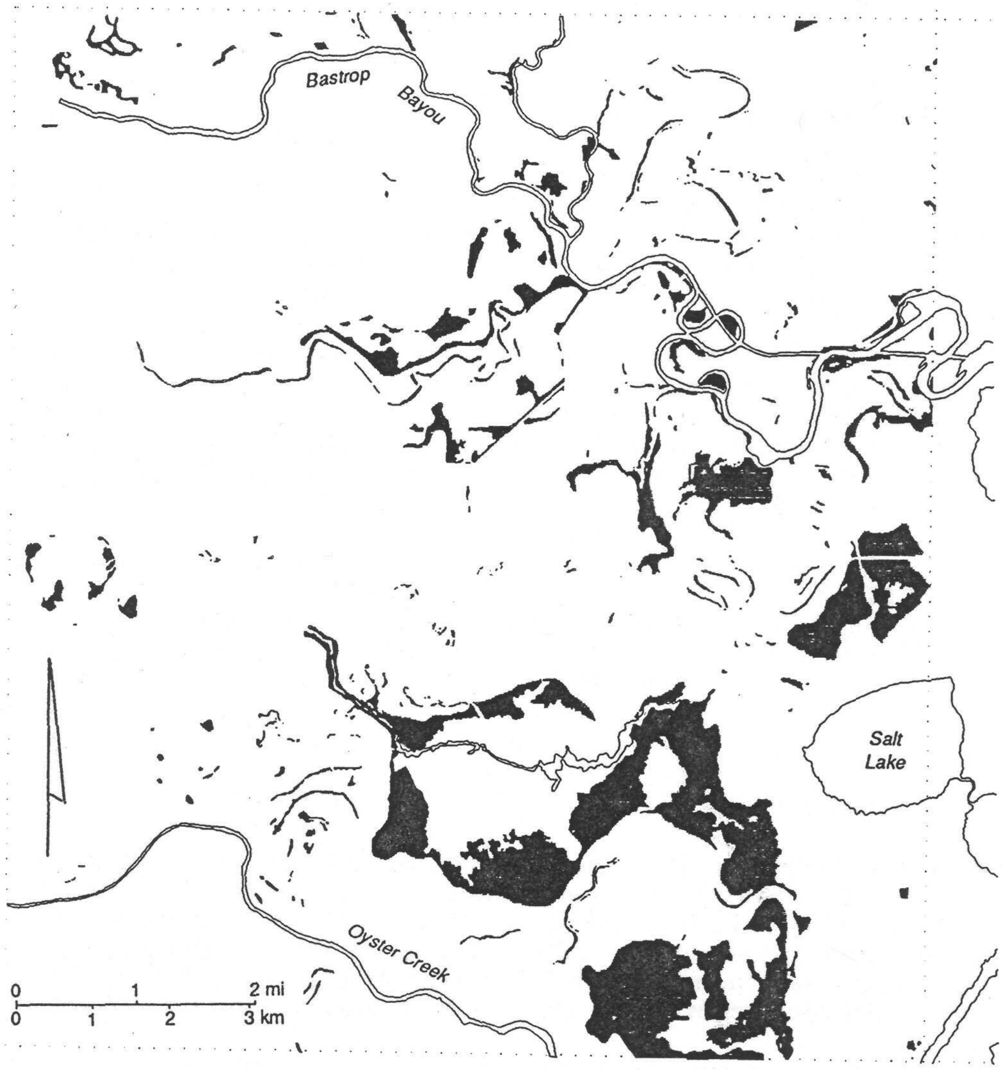

Figure 42. Distribution of areas (shaded) that changed from uplands (1950's) to emergent wetlands (1989) in the Oyster Creek quad. While some of the changes might be the result of photointerpretation, subsidence and faulting in this area are thought to have contributed to local changes from uplands to wetlands.

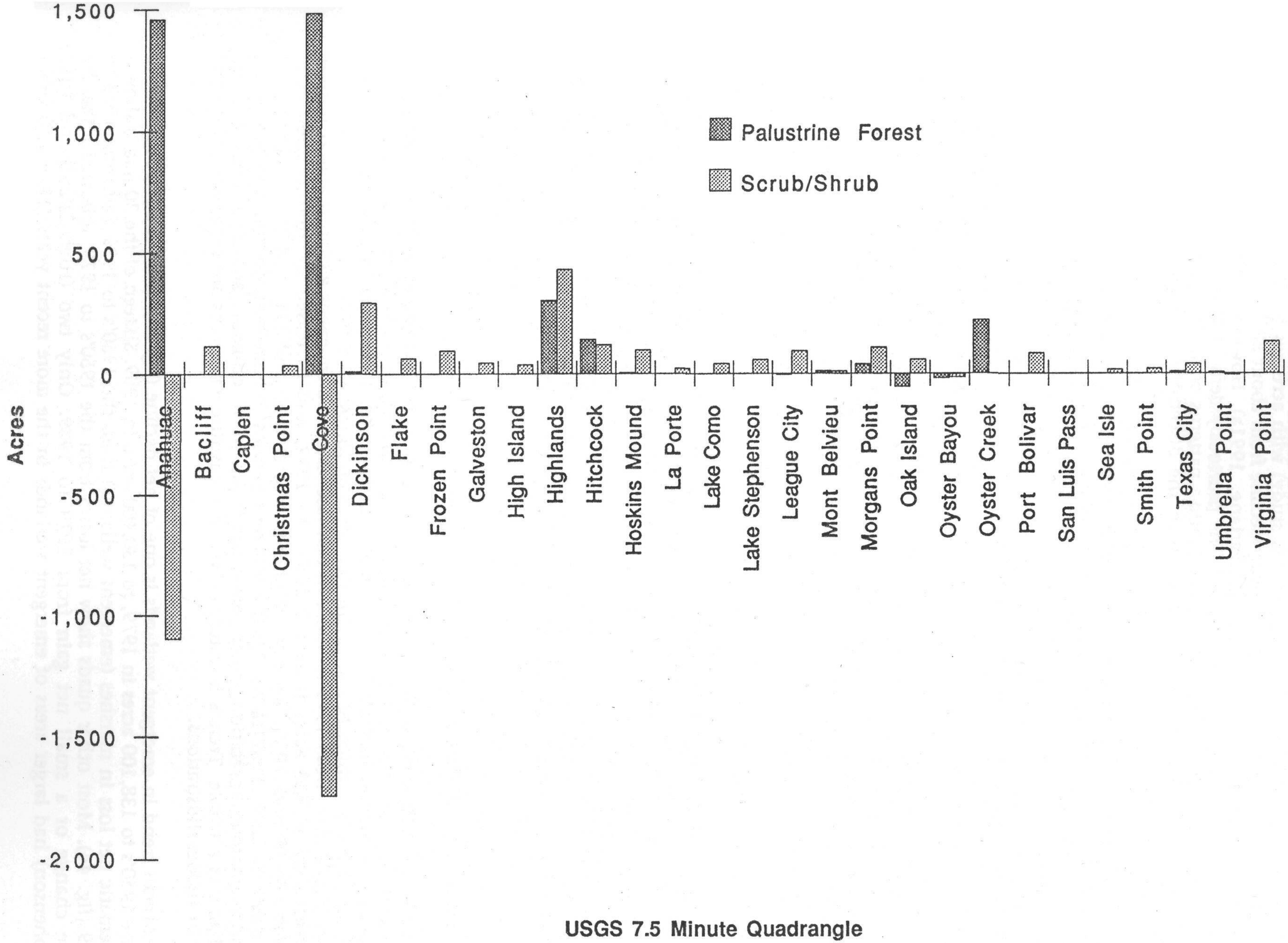

Figure 43. Net losses and gains (acres) in scrub-shrub and forested wetlands from the 1950's to 1989 for 7.5-minute quads in Galveston Bay system.

Comparison of 1950's acreages (used in this study) with acreages from 1975 and 1987 (Pulich and White, 1991) indicates a striking, steady decline from about 300 to near 200 acres in marine grass distribution in Christmas Bay (McFarlane, 1991a). However, the 1989 area of about 385 acres suggests a reversal in this trend. The previously defined downward trend may be due to annual and seasonal differences in distribution patterns of marine grasses, and to bay-water conditions that can enhance or interfere with the discernment of submerged vegetation on aerial photographs.

Accurate delineation of submerged aquatic vegetation on photographs can be inhibited by water turbidities and seasonal changes in distribution. Neither the 1950's nor the 1989 maps accurately reflects the total distribution of submerged vegetation that existed during maximum annual growth for those years. This is especially true in upper Trinity Bay, where fresher conditions exist and species with limited seasonal distribution such as *Vallisneria* are part of the rooted vegetation assemblage (Pulich and others, 1991) (fig. 29). In Christmas and West Bays, where extensive marine grasses were present in the 1950's, it appears that the true distribution could have been underestimated on the 1950's photographs because of high local turbidities. In contrast, conditions were favorable in Christmas Bay for delineation of the aquatic beds on the 1989 photographs because of low tides and turbidities. Thus, in Christmas Bay, part of the apparent gain in submerged vegetation from about 300 acres in the 1950's to about 385 acres in 1989, is due to photointerpretation. Still, these acreages suggest that the distribution of marine grass in Christmas Bay, while possibly fluctuating on an annual and seasonal basis (Pulich and White, 1991), has not changed substantially since the 1950's.

Trends: 1950's to 1979 to 1989

The mapped distributions of vegetated wetlands for the 1950's, 1979, and 1989 indicate substantial net losses over both periods. This downward trend is illustrated by acreages of 171,000 in the 1950's, 146,000 in 1979, and 138,600 in 1989. The rate of loss, however, decreased over time from about 1,000 acres per year between 1953 and 1979, to about 700 acres per year between 1979 and 1989. The rate of loss between 1979 and 1989 would be lower, less than 500 acres, if inaccuracies in wetland interpretation on the 1979 photographs were taken into account. Emergent wetlands decreased in area overall, whereas, together, scrub-shrub and forested wetlands increased in area (table 6, fig. 33).

Estuarine and Palustrine Emergent Wetlands

Estuarine and palustrine emergent wetlands represent, by far, the largest wetland system in the Galveston Bay complex for all periods (figs. 24, 30, and 31; plates I–III [at back]). The data on wetland distribution indicate that the most extensive losses occurred in palustrine emergent wetlands (table 6), which had apparent net losses of 15,600 acres from the 1950's to 1979, and about 10,000 acres from 1979 to 1989. In contrast, estuarine emergent wetlands appear to have decreased by 11,760 acres from the 1950's to 1979, and increased by almost 2,300 acres between 1979 and 1989. Because of photointerpretation problems and inconsistencies in emergent wetland classification for the different periods (see methods section and section on possible photointerpretation errors), emphasis is placed on estuarine and palustrine emergent wetlands as a whole. Trends in estuarine versus palustrine emergents are depicted in a general way in various illustrations.

The overall trend in emergent wetlands is one of net decline (fig. 33), from about 165,500 acres in the 1950's to 138,100 acres in 1979, to 130,400 acres in 1989. Sixteen of the 30 quads show a systematic net loss in marshes (emergent wetlands) from the 1950's to 1979 and from 1979 to 1989 (fig. 44). Most other quads show net losses from the 1950's to 1979, followed either by little change or a small net gain from 1979 to 1989. Only two (High Island and Lake Stephenson) had larger areas of emergent wetlands in the more recent years (1979 and 1989)

Table 6. Areal extent of vegetated wetland habitats in the 1950's, 1979, and 1989, Galveston Bay system.

WETLAND HABITAT	NWI Wetland CLASSIFICATION	1950's acreage	1979 acreage	1989 acreage
Salt and Brackish Marsh	Estuarine Emergent (E2EM)	117,640	105,880	108,160
Fresh or Interior Marsh	Palustrine Emergent (PEM)	47,850	32,250	22,210
Scrub/Shrub	Palustrine Scrub/Shrub (PSS)	3,430	2,300	2,570
Forested	Palustrine Forested (PFO)	2,040	5,580	5,650
Total		170,960	146,010	138,590

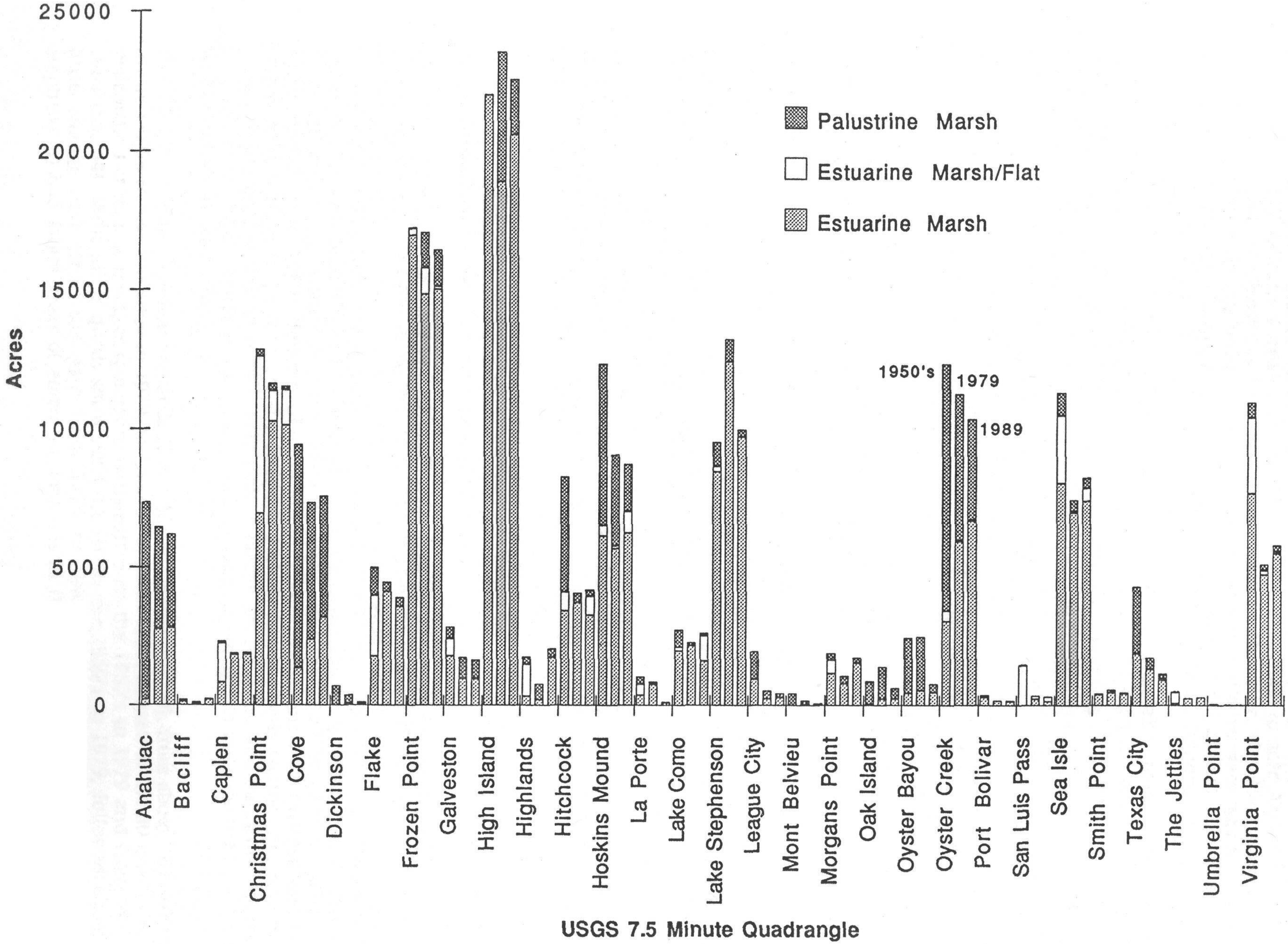

Figure 44. Areal extent of emergent wetlands (marshes) in the 1950's, 1979, and 1989, for the 30 quads defining the Galveston Bay system.

than in the 1950's. In both quads the wetland resource in 1979 was largest, indicating a gain from the 1950's to 1979, followed by a loss from 1979 to 1989 (fig. 44). The anomalously large area of emergent wetlands in the Lake Stephenson quad in 1979, however, is primarily the result of photointerpretation (see previous section on possible photointerpretation errors). Although wetlands may have increased in size during 1979 because of abnormally high precipitation, the 3,700-acre increase shown by the 1979 data for Lake Stephenson is unrealistic. The net increase from the 1950's to 1989 in this quad was less than 500 acres.

Quads with the largest net losses from the 1950's to 1979 are generally the ones with large losses discussed previously for the 1950's to 1989 period. They are Virginia Point, Hitchcock, Sea Isle, Hoskins Mound, Texas City, and Cove (fig. 44). The range in net loss in these areas is about 2,400 to 5,800 acres. This downward trend did not necessarily continue in each quad during the 1979 to 1989 period. In fact, the data show that in four of the six quads net gains occurred between 1979 and 1989 (Cove, Hitchcock, Sea Isle, and Virginia Point). Losses continued in Hoskins Mound and Texas City.

Scrub-Shrub and Forested Wetlands

Scrub-shrub and forested wetlands, together, increased in area over the two periods. Total area of these resources increased from 5,470 acres in the 1950's to 7,880 acres in 1979, to 8,220 acres in 1989. The scrub-shrub wetland habitat decreased from about 3,430 acres in the 1950's to 2,300 acres in 1979; it increased to about 2,570 in 1989. Mapped forested wetlands showed a systematic increase from about 2,040 acres in the 1950's to 5,580 acres in 1979 to 5,650 in 1989.

Major areas of scrub-shrub and forested habitats are confined to about four or five quads (fig. 45). These habitats commonly occur in the valleys of major rivers and streams, for example, the Trinity River (Anahuac and Cove quads), the San Jacinto River (Highlands quad), and Oyster Creek and Oyster Bayou (in quads of the same name).

Systematic trends are recognized in Cove and Anahuac quads where scrub-shrub wetlands decreased over each period, while forested wetlands increased (fig. 45). In the Highlands quad, which encompasses part of the San Jacinto River valley, scrub-shrub and forested wetlands, together, increased from the 1950's to 1979, and from 1979 to 1989. Over the latter period, maps of the Highland quad indicate an increase of scrub-shrub and forested wetlands from about 200 acres in 1979 to more than 800 acres in 1989. In the Oyster Creek quad, forested areas increased systematically from about 450 acres (1950's) to 650 acres (1979) to 675 acres (1989). In two areas (Oyster Bayou and Morgans Point), the 1979 scrub-shrub and forested wetland resources are considerably larger than in the 1950's and 1989 (fig. 45).

Estuarine Aquatic Beds

Estuarine aquatic beds could not be adequately mapped on the 1979 aerial photographs because of abnormally high tides and turbidities. For a discussion on changes, see the section on trends for the 1950's to 1989.

PROBABLE CAUSES OF WETLAND LOSSES AND LOCAL GAINS

The causes of wetland losses include both natural and artificial factors. Among them are relative sea-level rise (subsidence + eustatic sea-level rise) and draining and filling of wetlands for