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# Initial Effects of a Hurricane Storm Surge on Barrier Island Vegetation

by

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Florida Sea Grant College Program





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## INTRODUCTION

On Wednesday, October 4, 1995, Hurricane Opal, a Category 3 Storm, came ashore Santa Rosa Island, a barrier island south of Pensacola, Florida, with sustained winds of 125 miles per hour and reported wind gusts of up to 144 miles per hour. The eye of the storm appears to have been relatively poorly defined and, surprisingly, damage from the winds was not widespread or significant (this is perhaps a function not so much of the wind speed associated with Opal but of the fact that Hurricane Erin had followed approximately the same path only a month before Opal arrived and had already damaged or destroyed any trees or structures that might be susceptible to wind). Unlike with Erin, there was a storm surge associated with Hurricane Opal and the damage this phenomenon caused, both to natural and to human structures, was widespread and unprecedented.

Storm surges "...result from a piling up of water along the coast by the driving winds. Such 'hills' of water can be 5m or more above normal sea level." (Miller and Thompson 1979:172). Post-storm evidence indicates that the storm surge associated with Hurricane Opal was at least 2-4m high. While the storm surge struck all along Santa Rosa Island, the impact of the surge indicates that the strength of the surge increased eastward from the western tip of Santa Rosa Island where Ft. Pickens, a brick fortification built during the Civil War, is located. The western end of the island, including Ft. Pickens, is part of the Gulf Islands National Seashore, under the management of the National Park Service.

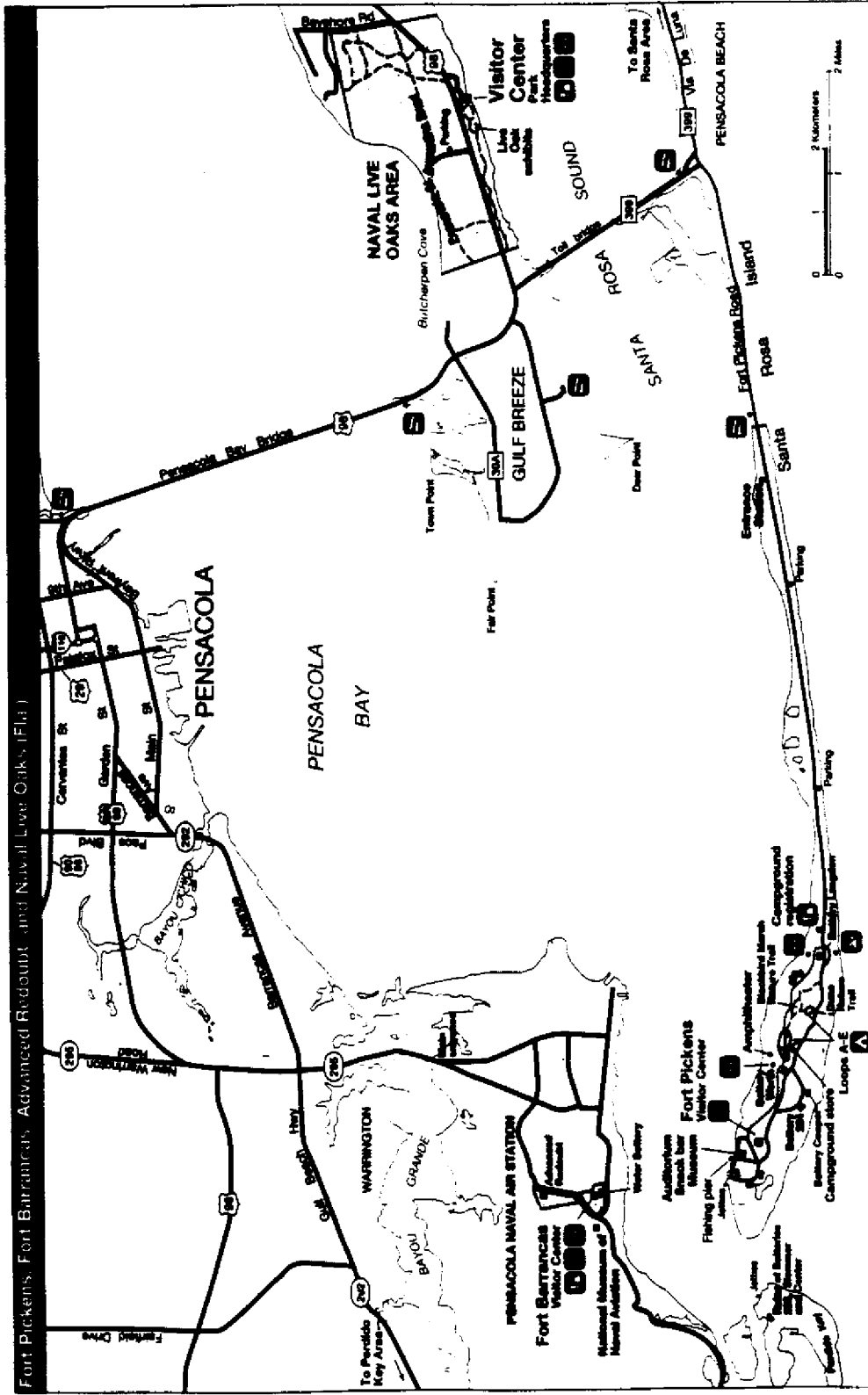
The destruction to Santa Rosa Island caused by the storm surge of Hurricane Opal created a regional emergency situation. Damage included the destruction of much of the infrastructure on the island, including water, electricity, telephone and sewer service. Roads were covered in several feet of sand or eroded away, making travel dangerous. Buildings were damaged or demolished and construction matter was scattered across the landscape, creating hazardous conditions for humans whether on foot or in vehicles. As a result, public access to Pensacola Beach had to be restricted to law enforcement and emergency agency officials until it was determined that the area was at least minimally safe. Within a few days, island residents were allowed to visit their property under controlled conditions and, eventually, sand removal and construction personnel were allowed to begin work. As of this writing (December, 1995), access to Santa Rosa Island is still restricted to residents except for certain hours during the weekend when the public is allowed to drive to a limited area of Pensacola Beach, but officials of the Gulf Islands National Seashore were kind enough to allow us access to their property within two weeks of the storm to gather the information necessary for this report. This report focuses only on the immediate effects of the storm surge and data presented came from the six week period from October 16, 1995 to November 26, 1995.

## LOCATION AND NATURAL LANDSCAPE

The geographical focus of this report is the Ft. Pickens Recreational Area of the Gulf Islands National Seashore. This area is located on the far western end of Santa Rosa Island and includes approximately eight miles of Santa Rosa Island from the western edge of the community of Pensacola Beach (see map). At its narrowest, the Ft. Pickens area (hereafter referred to as "the park") is slightly more than 0.1 mile wide, at its widest, this portion of the island is almost 0.7 mile wide (see map for location). The park is transected by a two lane paved road that runs E-W to the western portion of the seawall associated with the structure of Ft. Pickens, a Civil War fortification build of brick. Several smaller sub-roads go N-S to provide access to campgrounds and sites of interest.

U.S. Geological Survey topographic maps (the Gulf Breeze and Ft. Barrancas quads, both revised in 1992) show sand dunes along that portion of the park south of the road arrayed parallel to the Gulf or beach side of the island. A few dunal structures are shown on the north side of the road but they are more randomly aligned than those south of the road and closer to the Gulf. The maps indicate dune heights of 5-15 feet.

Before Hurricane Opal, the general vegetation pattern was one of typical dunal vegetation for northwest Florida. *Uniola paniculata* (sea oats) dominated the dunescape year round along with lesser populations of *Schizachyrum maritimum* (bluestem grass) and *Cenchrus spp.* (sandspur). Common shrubs included *Ceratiola*



## National Park Service Map of Ft. Pickens and Surrounding Area

Study includes that portion of Santa Rosa Island just east of the Entrance Station to the western tip

*ericoides* (beach rosemary) and *Conradina canescens* (minty rosemary). North of the road and in the western portion of the park, yaupon (*Ilex vomitoria*), palmetto (*Serenoa repens*), and sand live oak (*Quercus geminata*) occurred and stands of slash pine (*Pinus elliottii*) mixed with occasional sand pines (*Pinus clausa*) could be significant. A large bluestem prairie (*Schizachryrum maritimum*) has been established on the north side of the western end of the park. *Spartina patens* grew in swales where water stands and cattails (*Typha latifolia*) grew along the edge of the several small brackish water ponds.

## GENERAL STORM DAMAGE

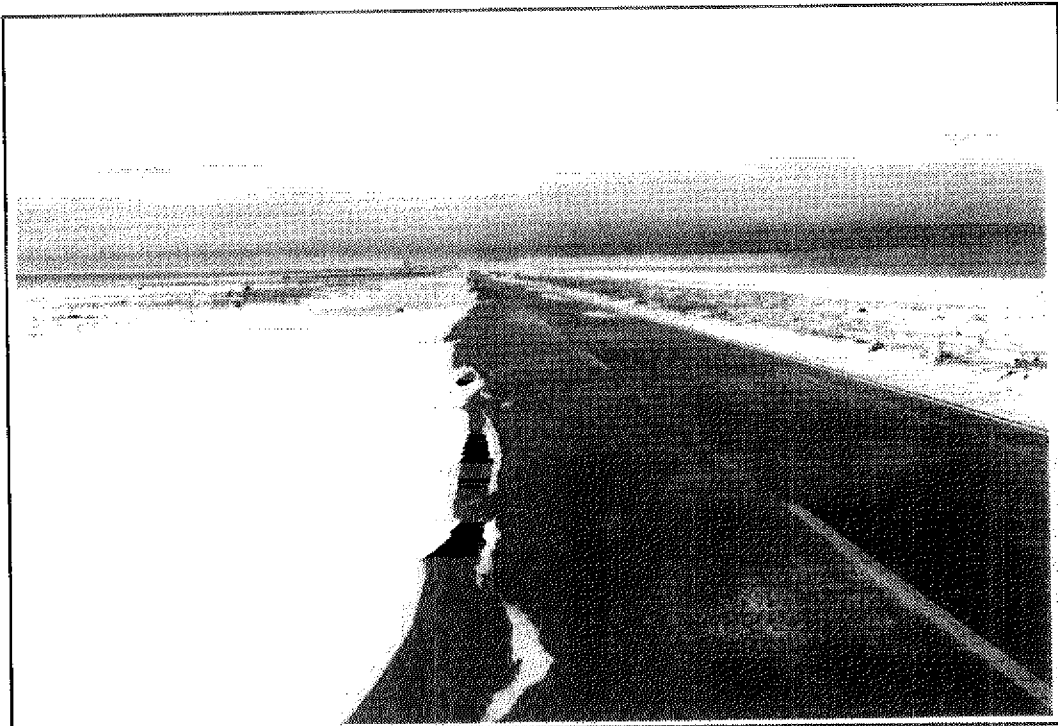
The storm surge associated with Hurricane Opal completely flattened the dunes in the Ft. Pickens area in the eastern portion of the park. From the entrance to the park, at what is locally known as Chickenbone Beach (just east of the Entrance Station on the map), for almost five miles westward, the landscape was leveled by the surge and almost all vegetation was uprooted and/or drowned in sand (see Figure 1). Except for occasional small relicts the surge somehow missed, there are no dunes in the park west from the eastern boundary until near the Battery Langdon beach area. At this point, the island begins to broaden and the erosive effects of the storm surge are limited to a narrow band along the Gulf.

In the eastern portion of the park, sheet flows of water leveled the dunes completely (see Figure 2). A building that once housed a park ranger office where entry tickets were sold is gone. The pavement in several parking lots which were on the Gulf side of the road was picked up, broken into small pieces, and strewn across the now flat sand field north of the road. The road itself was breached in many places and as water from the surge flowed across the road, increasing speed on that smooth surface, it plunged off the north side of the road and dug as deep as six feet into the sand, undermining the north side of the road. At least two crevasses occurred in this portion of the island allowing stream flow between the Gulf and the Sound. Judging from the deposits of sand along the south edge of three small ponds on the north side of the island, the surge carried several feet of sand almost completely across the island. There is evidence that sand was carried further than the southern edge of these ponds in lobal flow along low areas but higher areas on either side of the ponds did not have any newly deposited sand so it is probable that, even if water did cross the island at this point, eroded sand did not.

On the western portion of the island, massive dunal erosion was limited to a narrow area along the Gulf or South side. At least one line of dunes was destroyed along this shore but the dune fields are still intact. Water, however, obviously flowed into the dune areas even where erosion did not occur, seeking paths through the swales where they could be found. In some swales, waterborne debris lines were as high as eight feet on the slopes of the dunes and, although there is no evidence of significant erosion within this dune field, vegetation that is sensitive to salt water that either touches the plant or covers the roots was affected (see Figure 3).

## SPECIFIC VEGETATIVE EFFECTS OF HURRICANE OPAL AT FT. PICKENS

During the study period, a survey of the effects of the storm surge on the natural vegetation of the park revealed an interesting range of results. The storm surge sent a wall of Gulf water over the eastern portion of the parkland, essentially leveling all the dunes from Langdon Beach to the eastern edge of the park and destroying the original habitat. Westward of Langdon Beach, surge waters destroyed only the first line of dunes on the Gulf side but water did flow into the dune field through breaches in the second line of dunes and, as a result, low-lying areas were subjected to surge overwash and/or standing surge water for a period of time. In the latter situation, surge waters flooded completely to the north side of the island but only through relatively narrow channels that were existing wetlands. Both overwash and the creation of standing surge water modified plant habitats significantly and affected plants differentially. The following is a listing of plants common to the park during October and November and a description of the effects noted for each.



**Figure 1.** Ft. Pickens Road damaged by Hurricane Opal storm surge. October 1995.



**Figure 2.** View looking east from Langdon Beach area. The relict dune on the right is the last dune left on the Gulf side.





**Figure 3.** Uprooted sea oats plants piled up against a bush of *Solidago sempervirens* by flowing water.

*Baldwina angustifolia* - yellow buttons. These small annual herbaceous plants were in bloom when the hurricane struck. They, mixed with *Chrysopsis* and *Solidago*, gave the entire park a golden/yellow hue that is distinctively autumnal for this ecosystem. *Baldwina* grows extensively on dunes and, where plants were low enough on the dune structure to incur surge flow, they were browned out, presumably killed (samples of plants that had browned out were pulled up and generally had desiccating roots, implying death). Any saltwater overflow appears to have been fatal.

*Cenchrus spp.* - sandspur. This common pest grew everywhere in the park. Where storm surge sand flow uprooted plants but deposited sand on the uprooted plants, they could be seen sprouting through the deposited material. Plants that were uprooted and remained uncovered died. In the swale areas where surge water damaged or killed other plants, *Cenchrus* appeared not to suffer.

*Ceratiola ericoides* - beach rosemary. These woody low-lying shrubs were common in all the dunal areas of the park, preferring an open area but found also among stands of pines. Several carcasses of uprooted *Ceratiola* indicate that this effect of the storm surge could be fatal but there appeared to be no damage to plants from water flow or from sand deposition. This plant has significant root network density and appears to have functioned well in holding sand against water erosion.

*Chrysopsis godfreyi f. godfreyi* - Godfrey's Golden Aster. This plant is considered rare in Florida but grows well in the Ft. Pickens area. It is a common fall-flowering herbaceous plant, joining with other *Chrysopsis*, *Baldwina* and *Solidago* as part of the golden yellow carpet the dunes in the park exhibit in October. This plant grew everywhere on the dunes but completely browned out and presumably died when saltwater overflow occurred. After the storm, *Chrysopsis godfreyi* was a good indicator plant of the height of surge flooding in the dune fields that still exist in the western portion of the park.

*Chrysopsis godfreyi f. viridis* - Godfrey's Golden Aster. More common in the park than *C. godfreyi f. godfreyi*, this plant was a common fall bloomer in all dunal areas. We found healthy plants on the few relict dune segments that survived east of Langdon Beach and they, like other *Chrysopsis*, served as biological indicators of the height of saltwater surge in the ridge and swales of the dune regions. Browning and presumably death resulted from water overflow.

*Conradina canescens* - minty rosemary. A few carcasses of *Conradina* indicated that they did not survive uprooting by the storm surge but these hardy woody shrubs did not appear to react to flooding unless they were actually touched by the water. We found several examples of *Conradina* that were obviously in areas that flooded with the storm surge but they showed browning only as high as saltwater actually touched them. These plants looked perfectly healthy above what was apparently the water line. *Conradina* also appears to be an effective anchor for dunes in an erosive situation. We found examples of thickly matted *Conradina* roots holding the edge of relict dunes against erosion.

*Ilex vomitoria* - yaupon. The roots of this prickly woody bush also functioned as an effective anti-erosive agent and could be found holding the edge of relict dunes. Unfortunately, *Ilex* did not fare well with direct overflow of saltwater and, in those situations where we are sure that overflow occurred, yaupon plants were defoliated. Whether or not this was a temporary condition or a terminal one will be reported after a follow-up study planned for the Spring.

*Iva imbricata* - fleece bush. This bush commonly grows in open dune areas in the park. Washover with surge waters did not harm *Iva*; in fact, these plants continued to bloom through October and November even where post-surge evidence clearly indicated total washover.

*Juncus roemerianus* - needle rush. A relatively tall sharp grass normal found near wet areas in swales among the dune fields. Because of their habitat needs place *Juncus* in swale areas, they were susceptible to

overwash and standing surge waters in many locations. While the direct effects of surge flow was to uproot these plants, where they remained rooted, neither overwash, standing water or sand deposition of up to 18 inches significantly affected this plant.

*Lantana camara* - lantana. This colorful introduction to this region was limited in occurrence to the western end of the island, near Ft. Pickens itself. Where we found evidence of contact with surge waters, there was no evidence of plant damage.

*Opuntia pusilla* - prickly pear. Occurs throughout the park area where no major forest canopy is present. Sensitive to both uprooting and to salt water soaking, prickly pear did not fare well in surge overwash situations.

*Phragmites australis* - common reed or pond reed. Found in standing water, this plant grows in several wetland areas in the park. There were no situations in which overwash of *Phragmites* was indicated but, in those instances where surge waters obviously spilled into the standing water body where *Phragmites* grows, there was no evidence of significant damage.

*Pinus clausa* - sand pine. This species is found interspersed with slash pine stands but is sparse compared to the numbers of the latter in the park areas. *P. clausa* is found only on higher, better drained locations whereas *P. elliottii* grows also in poorly drained soils. Because of a preference for higher areas, no instances of significant surge flow affect was found in sand pine.

*Pinus elliottii* - slash pine. There was extensive browning of slash pine where there was evidence of surge flow. Small trees growing in the swales on the western portion of the island which obviously stood in saltwater for some time completely browned up and will presumably die. Large trees - up to fourteen inches in diameter - that grew in isolated stands on the eastern end of the park also browned up significantly. The latter suffered the brunt of the surge and may have sustained considerable splashing of saltwater as well as overflow. However, there are slash pine growing along the edges of the sound on the north side of the island in situations where their roots are almost completely exposed to saltwater wave action but these plants appear to be healthy. This may indicate that saltwater damage occurs only if the water touches and/or stands for some time on the upper trunk and limbs of slash pine. Large numbers of slash pine appear to be dying in the park as a result of the storm and a cursory evaluation on the eastern edge of Pensacola Beach indicated similar negative effects.

*Panicum amarum* - bitter panicum. Taller and more visible than sea oats but much less prevalent in the park, this plant's preferred habitat was the dune areas. Uprooted *Panicum* plants indicated that direct storm surge pressure could be fatal but, like *Uniola*, *Panicum* plants that remained covered with sand after uprooting demonstrated some ability to remain alive. *Panicum* stands on the north side of the island that were overwashed but not uprooted browned significantly but, within three weeks of the storm event, these plants were regreening.

*Polygonella gracilis* - wireweed or small leaved jointweed. This was a common plant in the dunal areas throughout the park; it was in bloom as the surge occurred. Usually interspersed with *Chrysopsis* on the dunes, it too browned up and died where surge waters washed over it. Another good bio-indicator of saltwater flow.

*Polygonella polygama* - October flower. Similar geographic distribution within the park and response to surge conditions as *P. gracilis*.

*Quercus geminata* - sand live oak. These trees are often windsculpted as they grow on the dunes but they were tenacious anchors for sand in the face of storm surge flow. The largest relict dune segment we

identified in the eastern portion of the park was held together primarily by the extensive root networks of *Quercus geminata*. They did not appear to respond negatively to saltwater overflow but, where uprooted, the effects were terminal (see Figure 4).

*Quercus hemisphaerica* - laurel oak. This hearty tree grows in the dunal areas where it is kept low and "tapered" by the wind. Overwash by storm surge resulted in browning and defoliation but, by three weeks after the surge event, new leaf buds were evident so immediate permanent damage was probably not inflicted. This plant is evidently a major positive factor in holding the dunes against surge erosion. Relict dunes in the surge areas often had *Q. hemisphaerica* as the dominant or secondary vegetative cover; often associated with the excellent anti-erosion plant *Q. geminata*.

*Schizachyrum maritimum* - gulf bluestem grass. This common dune resident appears to have been at least as hearty as sea oats. While not as prevalent nor as visible in the dune areas where *Uniola* dominates, this plant did grow in the eastern portion of the park and appears to respond to the surge event in the same way sea oat plants did. If sufficient portions of *Schizachyrum* plants are left covered in sand after the surge, the plants are sending out new growth. The extensive bluestem prairie areas on the north side of the island suffered very little damage. There was no actual surge in that portion of the park although there was some local flooding along ditches that flow through the prairie areas into the sound. Along these ditches where bluestem was clearly covered in water during the surge, there is no indication of damage to the plants.

*Serenoa repens* - saw palmetto. Found near or among stands of slash pine in the park, palmetto weathered surge conditions relatively well. Complete uprooting by water erosion resulted in fatalities but the large roots of palmetto defended the plants against the storm surge in locations where less tenacious sea oats were completely uncovered. Browning occurred where washover and or standing water was evident but, within two weeks of the surge event, new leaf sprouts were found as long as at least some portion of the root had remained uncovered.

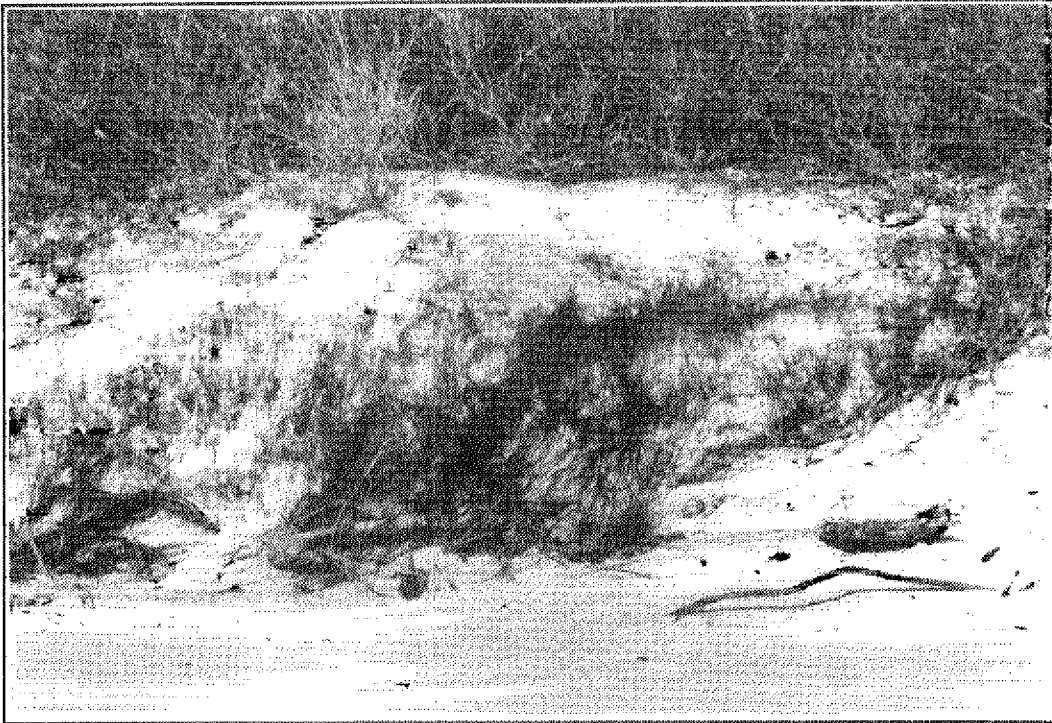
*Smilax spp.* - greenbriar vine. This prickly perennial is common in the wooded stands in the park. Surge overwash does not appear to have damaged these hearty plants although complete uprooting was fatal.

*Solidago sempervirens* - seaside goldenrod or woody goldenrod. Extremely common bush in open areas throughout the park, this plant was in bloom at the time of the hurricane. Although *S. sempervirens* was susceptible to uprooting where significant amounts of water flowed with the surge, overwash by and/or standing in surge water did not affect these plants. In fact, several weeks after the hurricane, *S. sempervirens* plants that had clearly been under salt water in the surge were blooming heartily.

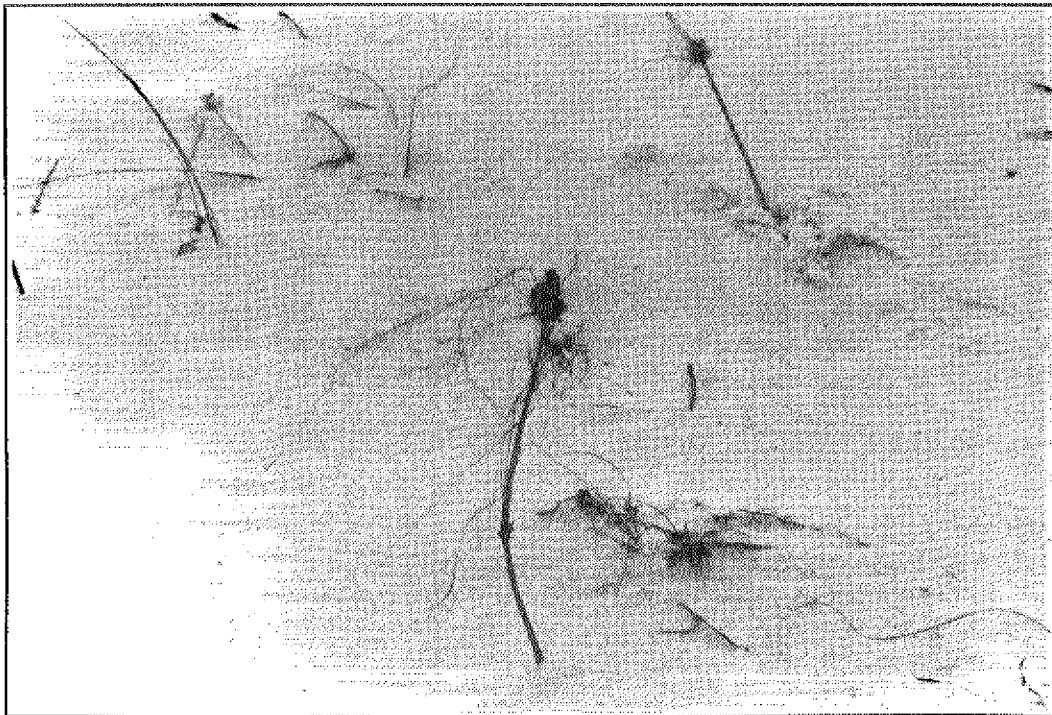
*Spartina patens* - salt meadow cord grass. This plant is normally associated with brackish-salty water and is common in swales in the dunal areas and near or in areas where water normally stands. Surge inundation of *Spartina* growing in swales resulted in significant browning although, within three weeks of the storm, new growth in browned stands could be seen.

*Typha latifolia* - common cattail. This plant was found only on the edge of pond areas in the park, growing in the water. Surge overwash resulted in total browning of the shoreward portion of a *Typha* stand in the pond near Ft. Pickens. *Typha* growing on the inland side of that pond, where overwash evidence was not found, however, did not indicate significant levels of browning even though the overall salinity level of that pond increased as a result of surge flow into it.

*Uniola paniculata* - sea oats. The plant most commonly associated with the dunes on Santa Rosa Island in the mind of the public, *U. paniculata* has certainly been the dominant vegetation on the south shore of the island. The storm surge uprooted sea oat communities readily (see Figure 5). While sea oats are generally assumed to be important in the dune building process (Salmon, et al 1982:7), the evidence at Ft. Pickens



**Figure 4.** Sand Live Oak roots protrude from the side of a partially eroded dune. Note the density of the root structure.



**Figure 5.** Sea oat roots exposed by Hurricane Opal storm surge at Ft. Pickens. October 1995.

indicates that this plant is not particularly effective at holding sand in place in a storm surge environment. Uprooting, by itself, was not fatal to *U. paniculata*, however. The storm surge eroded the dunes but it also deposited sand in significant amounts down-surge or, in this case, northward across the island. In those instances where the rhizomes of individual *Uniola* plants were able to remain covered with sand after the surge abated, survival rates appear to be good. In fact, in the eastern portion of the park where the storm surge damage was most spectacular, newly emerging sea oats were almost the only living vegetation noticeable 2-4 weeks after the storm surge event. Analysis of a small sample of these newly-sprouting plants revealed that the sprouts were from plants that had been buried often with up to 18-inches of sand. The knotted appearance of the rhizomes indicated that these plants had been moved to their present location, probably flowing and tumbling with the sand and water as the storm surge came across the island. They proved hearty in this environment.

Although it was heartening to see that large numbers of sea oat plants survived the storm surge, completely uprooted *Uniola* plants were also the dominant surface debris feature. By the second week after the storm, large piles of brown, brittle sea oat plants marked the path of the storm surge at Ft. Pickens. Based on laboratory studies of *Uniola* (Wagner, 1964), it is probable that the sea oat plants that were uprooted by the storm surge and remained uncovered after the surge abated died quickly.

*Vitis spp.* - wild grapes. These were found associated with wooded areas, growing in pine stands readily. Where surge overflow was evident, vines were defoliated but, within three weeks of the storm event, new growth could be seen along these vines.

## UNIQUE PHENOMENA

Approximately three weeks after Hurricane Opal crossed Santa Rosa Island, we noticed several ball-shaped bundles of vegetative material on the beach south of the pond near Ft. Pickens. Upon further investigation, we found these vegetative bundles in large numbers along the beach, interspersed with unconsolidated piles of vegetative matter. Subsequent field checks found both the bundles and the unconsolidated piles by the hundreds along all sections of the beach at Santa Rosa Island.

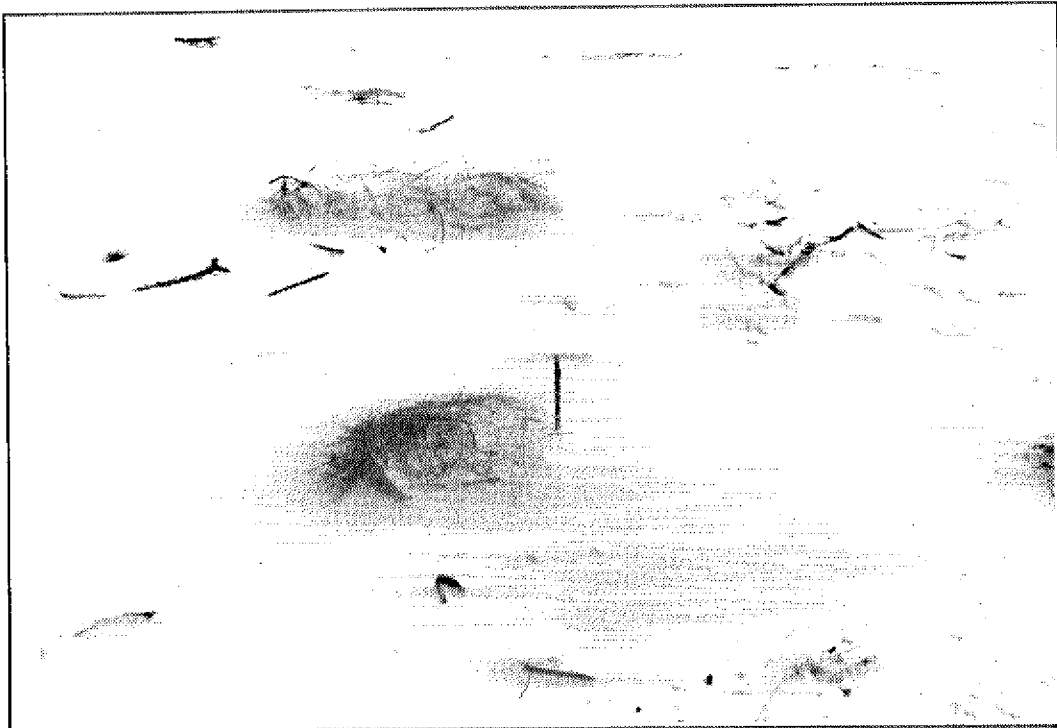
Obviously, these bundles (referred to hereafter as Pickens Bundles), as well as the unconsolidated piles of vegetative matter found with them, were the result of aeolian (windblown) forces; we witnessed both the bundles and the unconsolidated piles being moved by the wind on several occasions (see Figures 6, 7 and 8). The unconsolidated piles consisted primarily of *U. paniculata* plants, including leaves, rhizomes up to several feet in length, and secondary and tertiary roots. The bundles consisted primarily of smooth, rounded root/rootlet material that ranged in diameter from 36 microns to 64 microns (the mean diameter was 48 microns). Occasional sea oat leaf material was incorporated into these bundles as were very short pieces of rhizomal material. The erosion caused by the storm surge exposed *Spartina* and *Panicum* roots as well as *Uniola* roots but the secondary and tertiary roots of both *Spartina* and *Panicum* are heavily dendritic while the roots of sea oats are smooth. The incidence of uprooted *Spartina* and *Panicum* was significantly less than was that for *Uniola*; a result of both the original dominance of sea oats in the dunal vegetation regime and the fact that *Uniola* was particularly susceptible to uprooting by the storm surge. The primary material in Pickens Bundles was clearly roots from *Uniola paniculata*.

Pickens Bundles are tightly woven bundles of sea oat roots that natural aeolian movement forms into regular shapes. These shapes vary from almost cylindrical in the early stages of formation to elliptical or footballshaped to almost perfectly spherical. The density of the bundle increases as the bundle evolves from cylindrical to spherical and the assumption is that, given enough time, aeolian movement, and rootlet material, the ultimate Pickens Bundle shape will be spherical. The dimensions of ten bundles collected are as follows:

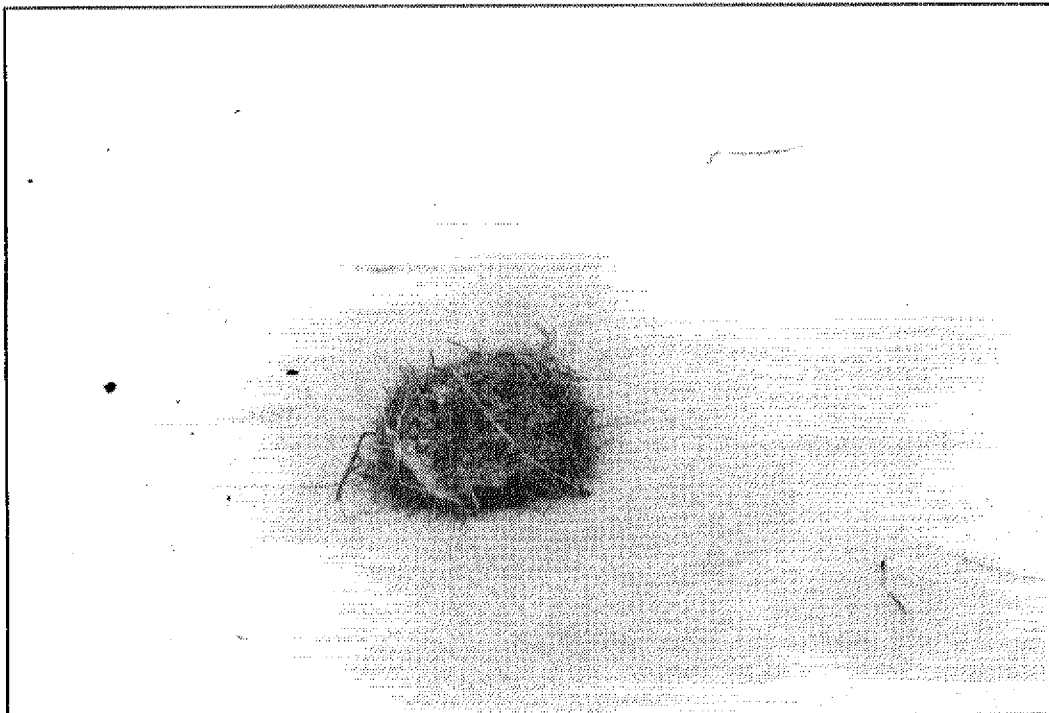
L - 4.25 in., W - 3.00 in.  
L - 7.25 in., W - 4.10 in.  
L - 6.20 in., W - 5.20 in.  
L - 5.25 in., W - 3.25 in.

L - 8.25 in., W - 6.00 in.  
L - 4.75 in., W - 3.25 in.  
L - 6.25 in., W - 5.75 in.  
L - 5.50 in., W - 3.75 in.

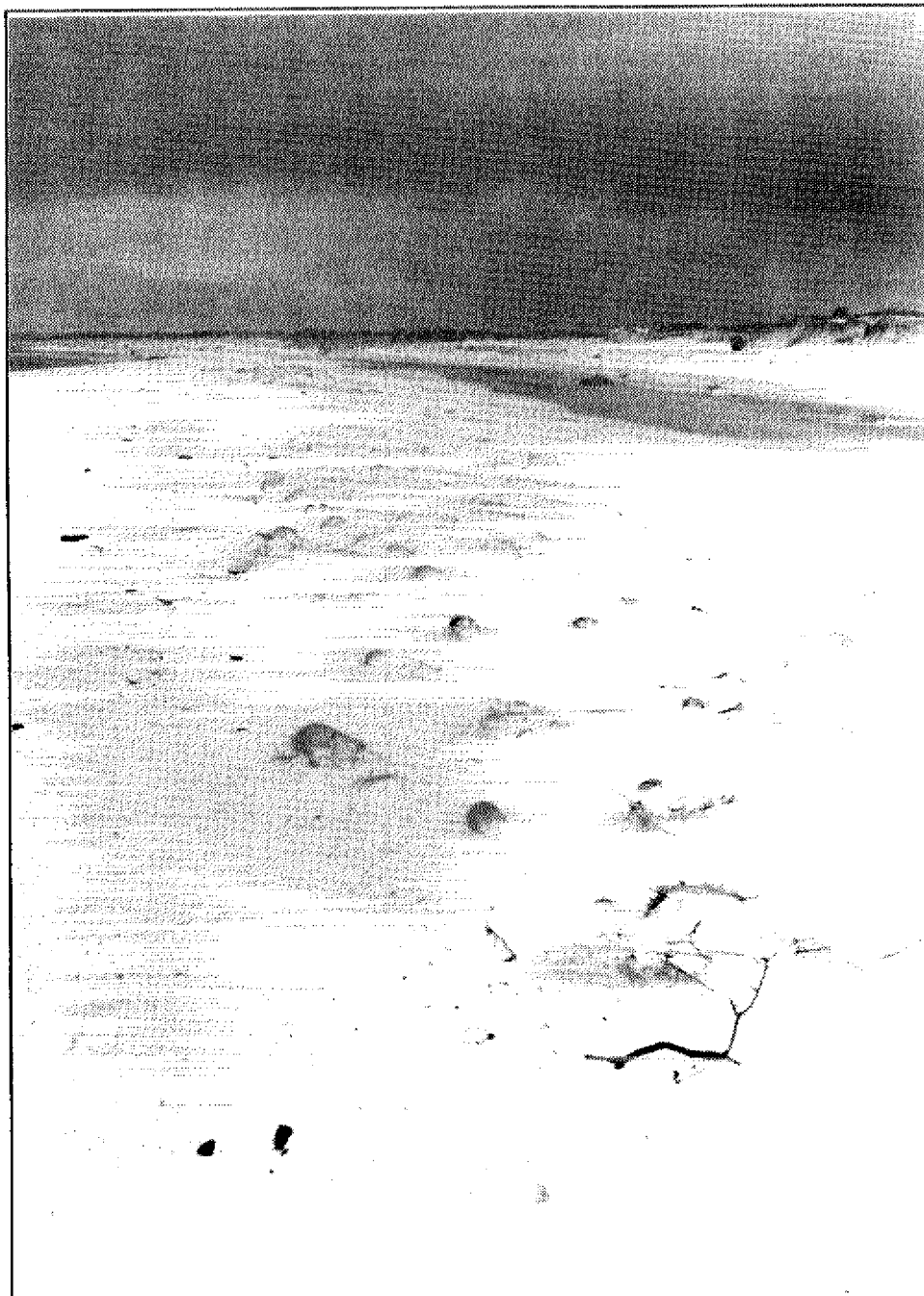
L - 8.75 in., W - 7.15 in.  
L - 7.75 in., W - 7.00 in.



**Figure 6.** Pickens Bundle partially buried in sand.



**Figure 7.** Close-up of Pickens Bundle after Hurricane Opal storm surge. October 1995.



**Figure 8.** A line of Pickens Bundles and unconsolidated vegetation piles near Ft. Pickens after Hurricane Opal. October 1995.



Inquiries of National Park Service staff stationed at the Gulf Islands National Seashore indicated a general lack of awareness of these bundles as a regular feature on the park beaches. One ranger had noted them in the past as random phenomena and assumed that they must be bird nests (as did one of my research associates upon seeing a bundle for the first time). Another park ranger remembered seeing similar bundles after Hurricane Frederick, which struck this area in 1976. Pickens Bundles appear to be naturally occurring aeolian phenomena that will form wherever *U. paniculata* plants uproot to create building materials (in fact, there is nothing to preclude the natural aeolian bundling of any vegetative material). The incidence of these bundles will depend primarily upon the availability of sea oat root material (the wind being assumed as a constant along coasts) and, the extensive uprooting and death of *U. paniculata* caused by a storm surge creates unprecedented amounts of bundle building material in the environment. The bundles will be short-lived phenomena, occurring only as long as there is sufficient dead vegetative material to supply the aeolian process.

Although Pickens Bundles were found on all sections of the beach, blowing between the edge of the water and the face of remaining dunes or other natural obstructions to aeolian movement when first recognized, subsequent field checks over the next few weeks indicated a significant change in this spatial pattern. As the bundles get heavier, from both added root material and as the weave of the bundle grows denser and the bundle begins to collect sand, aeolian movement slows. Apparently this occurs on a consistent basis because long rows of Pickens Bundles and piles of unconsolidated vegetative matter began to develop on the beach, parallel to the edge of the Gulf - where the eroded foredune was located.

The next stage in what appears to be a natural process found the Bundles and unconsolidated piles collecting windblown sand, in some cases as much as 18 inches of sand in a seven day period. It is hypothesized that this is the formative stage of the building of a line of dunes; that the vegetative matter provided by the uprooted sea oats which grew on the dunes before the storm surge destroyed the dunes is functioning as an integral part of the natural rebuilding of dunes along this beach.

This hypothesis is based on only a few weeks of field observation and will require continuing scientific analysis if it is to be upheld. That analysis is planned and results from that study should be available after a twelve or eighteen month period of study.

## CONCLUSIONS

The destruction Hurricane Opal wrought on the natural dune environment in the eastern portion of the Ft. Pickens park area was almost complete. Although the impact on man-made structures was not mentioned in this report, the damage to communities along Santa Rosa Island was devastating. Not only buildings were destroyed but the basic infrastructure of a modern community - roads, water and sewer systems, power lines, telephone lines, and television cabling systems - were all damaged or demolished. The human tragedy associated with Hurricane Opal is immense (see Figure 9).

Santa Rosa Island is a barrier island however, and, as such, hurricane damage, whether from wind or storm surge, should be expected periodically. Certainly this is not the first storm surge to flow across the Ft. Pickens area but, whatever the extent of damage similar events may have inflicted in the past, the dunes and a rather standard vegetation community associated with dunes in northwest Florida had been re-established before Hurricane Opal. Just as surely, the dunes will be rebuilt through natural processes, the first stages of which, if our hypothesis is accurate, may be significantly aided by roots from sea oats killed by the storm surge and now providing material for Pickens Bundles. As reported above, many of the plants found in the Ft. Pickens area showed remarkable resilience to the ravages of a storm surge. Those that could not survive the direct forces of the surge event were distributed widely enough, across differing eco-zones and at various elevations, to insure the survival of at least some individual plants. As part of the natural process, the plants that grow as an integral, functioning part of dune areas and survived the storm will colonize the new dunes. In the western portion of the park, dune fields remain and healthy vegetation grows on them, at least where surge waters did not flow. These plants are all wonderfully adapted to the sand dunes of Santa Rosa Island and, as they reproduce sexually or vegetatively, their offspring will spread to the rebuilding dunes, recreating, as closely as possible, the coastal community that existed at Ft. Pickens before Hurricane Opal.



**Figure 9.** Among the massive home destruction, Pickens Bundles and vegetative material line the Pensacola shore. November 23, 1995.

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