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Development Planning For Barrier Island Maritime Forests

During the last twenty years, the importance of ensuring proper land planning and landscape management on barrier islands has been firmly established. Culminating with the passage and implementation of the North Carolina Coastal Area Management Act of 1974, the overall planning and management process for barrier islands has substantially improved the balance between island development activities and the ability of the barrier island to maintain its essential ecological and geomorphological functions and processes. In the context of current comprehensive planning efforts for barrier islands, maritime forests have become the last major component of the island system which has yet to come under strong regulatory control.

Although considerable development in maritime forests has occurred in the past, only recently have researchers come to more fully understand the strategic role that maritime forests play in the overall maintenance of the barrier island ecosystem. Growing recognition of the maritime forest's functional importance coupled with the prospect of increased development activity and a firmly entrenched planning and regulatory framework suggests that management of the maritime forests could prove to be a key planning issue on barrier islands in the 1980s.

Although a case will be presented establishing the importance of the maritime forest, a discussion of the merits and drawbacks of coastal area development will not be undertaken. Development will occur on the barrier islands. The relevant issue is how to plan for development without compromising the public's interest or stifling the private sector. In the case of maritime forests, the answer lies in clearly formulated land use policy, effective though not crippling regulation, long term research, and economic incentives. What is intended here is to put the issue of maritime forest management into a more complete perspective for those involved with coastal area development.

Before describing one example of innovative maritime forest management initiated through the private sector and later presenting some comments on regulatory controls, a review of the structural and functional characteristics of maritime forests will provide a context through which management concepts can be explained. The description of maritime forests and their management concepts can be applied to most situations; however, the physical character of each barrier island and its particular maritime forest is largely controlled by local physical, ecological, and sociological forces. Therefore, management strategies must be tailored to fit each island's particular forest and the development pressures it faces. For the remainder of this article, Bogue Banks, located on the southeastern North Carolina coast near Morehead City, will be used as a vehicle for interpreting the maritime forest and the problems encountered in its management.

STRUCTURE OF THE MARITIME FOREST

Various forms of maritime forests can be found along coastal environments worldwide. There is some debate as to the precise definition of a maritime forest but those present on the North Carolina coast can be best described as oak-juniper-holly-pine-dominated forests on barrier islands or immediately adjacent to estuarine waters that have developed under the influence of salt spray. In this case, we will restrict our consideration to those maritime forests found on Bogue Banks. For management purposes, all stands of woody vegetation on the island will be considered as some form of the maritime forest community.

The primary physical forces which control the structure and composition of maritime forests are wind, salt spray intensity, and topographic

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position, with the incessant salt spray of this oceanic environment being the single most important factor. Depending on the proximity of the forest to the ocean, its topographic position, and its exposure to salt spray, the maritime forest may exhibit several different physical forms and spatial arrangements. Closer to the beach, the forest's presence is shielded by the foredunes and is manifested in a dwarf form, often less than three feet in height. The trees, shrubs, and vines are massed into a shrub thicket with a tightly woven, inter-connected, sheared canopy.

The effects of the salt spray and wind not only limit the forest's composition but also give the forest canopy its well known asymmetrical windswept form. While fine sand particles carried by the wind damage the exposed leaf surfaces, magnifying the toxic effect of the salt, higher salt concentrations coincide with the growing season, damaging new growth and terminal buds. This combined interaction results in increased lateral branching toward the top of the tree or shrub and encourages elongation of branches on the protected leeward side of the plant. The canopy in this intense salt spray shear zone of the forest is a finely woven network of interlocking canopies forming a common physical unit which may extend over many acres of forest. In this way, the individual plants in the maritime forest work collectively to reduce the amount of each individual's surface area exposed to the salt spray, protect the understory and forests behind it, and provide extraordinary resiliency to potentially destructive high winds.

Two points need to be re-emphasized here due to their fundamental importance to the formulation of an effective management strategy for the forest. Wind and salt spray are the overriding factors which control the structure and composition of vegetation growth in the maritime forest; moreover, the forest canopy in the salt spray shear zone functions essentially as a single unit providing protection to the area beneath it and the remainder of the island in its leeward shadow. Because of its proximity to the ocean, the shear zone will come under more development pressure and will be most vulnerable to impacts resulting from development activities.

FUNCTIONS OF THE MARITIME FOREST

The maritime forest is unique not only in its limited distribution, physical form, and species composition, but also in its functional capacity. Although the unusual resiliency and physical character of the maritime forest surely preserves its own integrity and ensures a favorable degree of environmental stability, the presence of the maritime forest plays a significant role in the long-term maintenance and stability of the entire barrier island. Maritime forests serve to conserve groundwater by reducing evaporation; utilize and recycle scarce nutrients in a relatively sterile environment; aggregate soil material, thereby gradually elevating the island; provide some measure of hurricane protection; and serve as a major stabilizing component of the overall barrier island system (Bellis, et al., 1976).

Beside the long-term dynamism of the barrier islands as sea level slowly rises, daily and seasonal forces influence the maritime forest and any development on the island. The two main short-term forces are wind erosion and periodic oceanic storms and hurricanes. Winds of only ten to fifteen mph will initiate sand movement; moreover, winds on many islands will exceed forty mph during any month of the year (Au, 1974). Where present, healthy and self-perpetuating maritime forests serve as the primary stabilizing force for shifting sands on the interior portions of the barrier island. In some cases maritime forests are being overrun and completely covered by encroaching active dunes. However, the forest typically is in a tenuous balance with the wind and sand, and in many cases is slowly colonizing and stabilizing previously unforested areas.

"MARITIME FORESTS PROVIDE THE ONLY TRUE PROTECTION FOR DEVELOPMENT ON THE ISLAND DURING A HURRICANE."

Undoubtedly, the most destructive and potentially devastating forces for barrier islands and their associated land development are severe storms and hurricanes. Maritime forests provide the only protection for development on the island during a hurricane. By deflecting the brunt of hurricane-force winds, maritime forests have proven to be the most effective protection for island buildings. The reason behind this lies in the physical character of live oak and other forest species which are extremely resistant to strong winds and uprooting due to their well established root system, low center of gravity, and resilient wood. The protective features a healthy maritime forest offers for a residence on the island is incomparable, and if not properly managed, essentially irreplaceable.

Clearly, the distinct structural and functional aspects of the maritime forest which have provided for its development and maintenance on the barrier islands are precisely the features which can be used to protect associated island development. The core of any effective forest management strategy should be formed around these features which characterize a properly functioning maritime forest.

IMPACT OF DEVELOPMENT ON MARITIME FORESTS

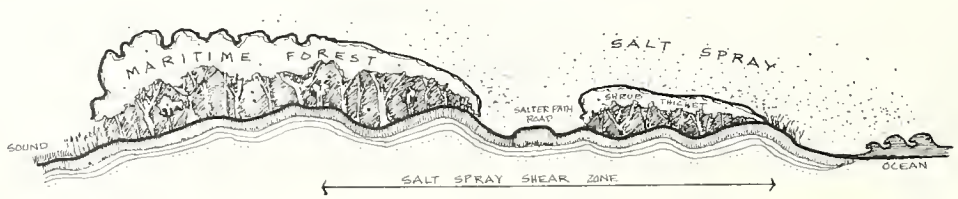
From a land use perspective, the significance of the adaptive morphology and functional roles of the forest cannot be overlooked. The management implications of the fact that maritime forests generally represent the most stable sites on the island is self-evident. Areas which are presently forested are generally the safest and most reasonable areas in which to build. If their protective functions are to be retained, development must adhere to sound management practices for the forest based on a fundamental understanding of the dynamics which control their formation.

Slight changes in the existing environmental conditions can disrupt the stability created through the establishment of the maritime forest. Where the foredunes or the maritime forest has been completely cleared, an increase in salt spray exposure, the initiation of shifting dunes, or sea-water flooding is likely to occur. Obviously, clearing the forest will in some way neutralize the protection previously provided to development by the maritime forest. For this reason, management strategies for protecting the maritime forest must be formulated around reducing the potential impact of increased salt spray, migrating sands, and saltwater immersion.

Thus, from an ecological and management perspective the salt spray shear zone should not be violated. This makes sound ecological sense, but unfortunately flies in the face of coastal development economics. Oceanfront lots often represent the profit margin for developers that can allow them to develop less densely on the sound side of the island. The extent of impact that development activities will have in these areas is dependent on the existing environmental conditions, the type and extent of the disturbance, the efforts made to protect the forest during construction, and the post-construction efforts to rehabilitate the forest. In terms of reducing the impact of salt spray, a number of basic planning and construction guidelines should be considered:

1. Avoid siting buildings or roadways on exposed sites at higher elevations. The impact of salt spray increases with closeness to the beach and at higher, more exposed elevations.
2. Do not clear the understory of the residual forest. The understory reduces salt penetration beneath the canopy.
3. In all cases, leave the leading edge of the forest which fronts the ocean intact. This will help prevent the initiation of dune migration, and help reduce the risk of damaging salt water flooding. It is the key feature in the entire forest's canopy. The elevation and extreme exposure of the frontal edge makes regeneration and re-establishment of this critical component of the maritime forest difficult.
4. Avoid clearing large areas of forest. Clear only as much forest vegetation as is needed for the actual construction of a building or roadway. Where feasible, align roadways parallel to the ocean and, if possible, less than forty feet in width. This will help to reduce the effects of salt spray on the newly exposed trees.
5. Efforts should be made to site buildings behind dunes and below the existing canopy line.
6. In sections of residual forest, leave as large an area as possible of continuous canopy intact. If a large enough stand is not left, given the existing salt spray concentrations, the entire group of trees will likely be eliminated in a few years.
7. In areas of long continuous cuts, salt spray fences have proven to be very effective in reducing die-back of newly exposed vegetation. However, by encouraging the growth of less salt-tolerant species behind the protective cover, re-exposure after the fence is dismantled

Figure 1. Diagrammatic cross-section of maritime forest near West Pine Knoll Shores on Bogue Banks. *Graphic by V. Zucchino*



might renew the die-back process. Some suggest allowing the exposed forest to naturally re-establish its canopy angle, a process that may be well underway after four to five years (Seneca, 1979).

8. As permitted by construction schedules, avoid clearing the forest during early spring and summer when new growth is particularly susceptible to salt spray damage.
9. Strong consideration should be given to the use of low pressure ground absorption septic systems. The shallow, narrow trenches used in low pressure systems can be installed with a limited amount of tree removal and canopy disturbance.

In terms of efforts to rehabilitate the residual forest, several actions can be taken:

1. Place salt spray fences in front of newly exposed sections of forests that can be expected to receive high levels of salt spray. Revegetation with native shrubs and trees can also be used to protect the forest and encourage the re-establishment of the canopy angle.
2. Stabilize cleared dunes or other open sandy areas with appropriate grasses (sea oats or American beachgrass) to prevent any encroachment of shifting sand at the base of the remaining trees.
3. Help save individual trees and shrubs by removing damaged branches, attending to trunk scars, and through fertilization and watering.

Figure 2. Salt damage to forest vegetation exposed by realignment of Salter Path Road on Bogue Banks. Note newly formed basal sprouts in foreground. Photo by L. Zucchino

Two less immediate impacts on the forest -- lowering of the water table and depletion of nutrients -- have also been noted. Lowering of the water table can be partially attributed to the combined effects of development activities, including excessive pumping of groundwater, increased stormwater runoff, and increased evaporation from reducing forest cover. The maritime forests may be subjected to drought conditions as the water table drops below the root zone and may also be damaged by saltwater intrusion into the freshwater aquifer of the island (Bellis, 1969). Secondly, as a nutrient-sensitive ecosystem, there is some evidence that the ready availability of nutrients, particularly nitrogen, may be significantly diminished as a long-term effect of excessive forest removal (Bellis, pers. comm.).

THE BOGUE BANKS EXPERIENCE

The value of the protective features of the maritime forest was not unknown to the early settlers of barrier islands. A number of fishing villages were established on the islands in the early eighteenth century, nearly all of which shared one common characteristic: the village structures were placed on the sound side of the island within the protective cover of the maritime forest. The village of Salter Path on Bogue Banks is an excellent example of early spatial relationships between buildings, the forest, and the ocean.

The emergence of a less sensitive approach to development within the maritime forest on Bogue Banks and other islands took precedence after World War II (Pilkey, 1976). Essentially unchanged since that time, large scale and piecemeal development has continued to devastate the maritime forests. The driving forces behind this approach mirrored the gridded tract subdivisions that were mushrooming on the mainland. An increasing market demand for oceanfront lots and the relatively unsophisticated techniques employed by developers of the era resulted in the wholesale destruction of maritime forests and in some cases resulted in the severe alteration of the fundamental structure of the barrier island system. Ecological research on maritime forests had begun but was primarily limited to descriptive ecological studies. Some researchers were beginning to study the influence of salt spray on the vegetation and the integral relationship that existed between the forests and the long-term maintenance of the islands.

The complex land planning and regulatory framework that now overlays the land development industry had not yet been established after World War II. Developers were not nearly so constrained by regulatory agencies nor were they aware of the role that dunes, forests,

and marshes had in the long-term protection of their developments.

While the development of the island accelerated, two events had considerable impact on the tone and direction which land use planning regulations and land development projects have taken on barrier islands and on the subsequent treatment of maritime forests: the extremely devastating Hurricane Hazel of 1954 and, twenty years later, the passage of the North Carolina Coastal Area Management Act.

Hurricane Hazel brought to bear the devastating effects that hurricanes could have on poorly sited developments. Although memory of the damage caused by Hazel has dimmed for some and is virtually inconceivable to many island newcomers, many homeowners on Bogue have consciously integrated their homes into the maritime forest for protection, for privacy, and for the image of being sensitive to natural surroundings. A tour of new home construction sites in the maritime forest on Bogue will reveal that such efforts are becoming the rule rather than the exception they were only a decade ago.

The Coastal Area Management Act provided the legal framework for the formulation and implementation of comprehensive land use planning objectives for the barrier islands and other coastal areas. The proliferation of federal, state, and local regulations to help ensure proper development on barrier islands has served to significantly reduce the net amount of land available for development on the islands. Moreover, by limiting development in ocean hazard areas, estuarine shorelines, designated natural areas, and flood-prone areas, greater development pressure has been placed on the interior portions of the island, much of which is presently forested on Bogue Banks. So, not only has the pace of development increased, but the amount of available land has been decreased leaving maritime forests in a potentially precarious position.

"...LARGE SCALE AND PIECEMEAL DEVELOPMENT HAS CONTINUED TO DEVASTATE THE MARITIME FORESTS."

A third and equally important influence on the development of barrier islands and maritime forests has evolved over the past decade: a marked shift in consumers' perceptions of what constitutes quality coastal development. A significant segment of the market has come to associate quality development with the well planned, "ecologically sensitive" communities and developments that became the symbol of proper coastal development in the 1970s. The most notable examples of this type of development are Amelia Island and Sanibel Island on the Florida coast, Sea Island in Georgia, and Hilton Head Island off the coast of South Carolina.

Many of the innovative planning, design, and marketing strategies used in these well-financed efforts have migrated north and found their way to the North Carolina coast. Although developments directed toward proper island development are not pervasive on the North Carolina coast at this time, the handling of maritime forests undergoing development has improved considerably since the 1950s. Interestingly, this improvement can be attributed more to an enlightened market demand and appreciation for the aesthetic and protective features of the maritime forest than to any influence from the regulatory process.

One development in North Carolina that embodies many of the issues discussed so far is the West Pine Knoll Shores development on Bogue Banks.

THE WEST PINE KNOLL SHORES DEVELOPMENT

The West Pine Knoll Shores condominium development is under construction on a 135-acre tract on Bogue Banks within the incorporated limits of the town of Pine Knoll Shores. The tract encompasses the breadth of the island from ocean to sound for nearly a mile between the Roosevelt Natural Area and the western limits of the town. The tract, owned by one part of the Roosevelt family, once included the adjacent acre section which was donated to the State as a natural area in 1971. The remainder, zoned for commercial development by the town, was retained for development purposes. The donation of the Natural Area reflected the Roosevelts' commitment to environmental conservation. The quality of the development efforts on the remaining acreage attest to the family's willingness to take the necessary steps for responsible development of the island.

Preliminary planning studies for the tract revealed a number of constraints for the project, both regulatory and ecological. Given 135 acres, less than 75 acres were available as suitable building sites. The remaining undevelopable acres were represented within either the CAMA-designated ocean hazard zone or estuarine areas, within the flood hazard zone delineated by the Federal Flood Insurance Program, within a fifty foot setback from the main island road required by the town, or as recreation areas, open space, and roadways planned for the development. One important implication of these constraints was that nearly all the developable sites were in areas covered by dense maritime forest, much of which lay within the salt spray shear zone.

Figure 5. Ocean Grove units carefully sited within a well maintained shear zone portion of the maritime forest. Photo by L. Zucchino

With these identified constraints, a very real concern for the developers became how to develop the tract at the highest reasonable density for economic return while preserving the integrity of the forest for its functional benefits. Of equal importance from the developers' viewpoint was the distinct island character afforded by the maritime forest which was seen as a very effective marketing advantage. Thus the maritime forest became an influential element in the overall land planning, site layout, architectural design, and marketing strategies for the development.

One of the most effective planning tools for protecting sensitive environments is the cluster development concept. Cluster development of a maximum number of units is a distinct advantage in the case of maritime forests. Given the opportunity to cluster, a net density of eleven units per acre and a gross density of five units per acre was achieved for the entire 135 acres. With a market projection of approximately 800 units for the development, the clustering option resulted in less extensive and more cost-effective road, sewer, and utility systems while disrupting a significantly smaller portion of the tract. As a result of the trade-off for higher density, more than fifty acres were left as open space, a considerable portion of which was undisturbed maritime forest.

The first phase of the development, Ocean Grove Condominiums, provided a test case for the entire project. Could seventy-two units be sited on ten oceanfront acres while maintaining the protective and visual character of the frontal dunes and maritime forest? Of ten acres, only six acres were available for buildings, parking, access, and pool areas after excluding required setbacks. Through finely-tuned site planning, sensitive architectural design, and exacting construction supervision, some surprising results were achieved.

A design and construction strategy was carefully formulated to integrate the given economic and architectural package into the maritime forest with minimal impact. The following concepts were incorporated into the design and construction process for the Ocean Grove Condominiums:

1. To retain the desirable visual and spatial character of the forest, as much as possible of the existing forest was left intact through: sensitively sited, tightly-clustered units, the use of narrow access drives and parking beneath units.
2. The architect's design of the condominium units offers limited wind resistance and encourages laminar flow above the units; integrates the units as closely as possible into the forest, with the units located within several feet of the canopy in many cases; takes advantage of the canopy's ability to reduce summer heat, winter winds, glare, and traffic noise; and reduces grading costs and the amount of disturbed area by stepping the units' foundations up the dunes.
3. When an area was developed all trees greater than eight inches in diameter and all trees to be saved were clearly marked before grading, units were sited to preserve intact stands of continuous canopy within the cluster, and constant supervision was given to grading and building crews to prevent additional forest damage.
4. Pedestrian systems were elevated boardwalks within undisturbed forest, constructed beneath the forest canopy where possible. They were designed to minimize the number of canopy cuts perpendicular to the ocean and to reduce the amount of "edge cut" in the forest by consolidating pedestrian traffic within each eighteen-unit cluster.
5. Landscaping efforts included stabilization of exposed dunes with native grasses and rehabilitation of exposed forest edges with proven native and other salt-resistant plant materials, careful maintenance of damaged and residual trees, use of permeable turf stone paving material in parking areas to improve groundwater recharge, and plans to transplant native plants from construction areas for landscaping purposes.

The first phase of the West Pine Knoll Shores development is nearing completion. Similar standards for the conservation of maritime forests will be included in subsequent development phases. As more experience is gained the strategies and techniques will be refined.

Clearly, the West Pine Knoll Shores development does not represent a simplistic, altruistic attitude by the developer, but more realistically, it was molded by a complex matrix of regulatory, economic, market, ecologic, and design parameters. In this case, the private

sector has accomplished a degree of conservation for the maritime forest that regulation might not be able to do as successfully.

More importantly, the development sets the pace for what can be accomplished through proper planning and design and it will have a positive influence on other coastal developments. The successful sales for the condominium units certainly can be partially attributed to a more enlightened market which is willing to share enough of the expense for protection to justify the developer's extra effort and costs required to conserve a valuable resource. Of course, not all developments can be expected to be quite so responsive to the requirements of the maritime forest. A limited amount of regulatory control will be necessary to ensure that at least the fundamental integrity of the maritime forest is protected, leaving the additional efforts for protection with the private sector.

FORMULATING A MANAGEMENT STRATEGY FOR MARITIME FORESTS

The structure, function, and dynamics of maritime forests and associated development impacts have been addressed in an effort to establish the importance of developing effective forest management strategies. Two basic strategies must be noted when considering the impact of land development activities on the maritime forest. First, clear policies must be developed by state and local planning agencies which will determine in which areas and in which part of maritime forests development will take place. Second, state and local planners, developers, and homeowners must agree on and understand the significance of the maritime forest, how it should be handled during the development process, and how the residual forest should be managed after construction.

In terms of federal, state, and local planning, only limited efforts have been made to formulate a clear and effective policy toward protection of maritime forests. Other than an increasing awareness of the problem by public agencies, the dominant regulatory influence to date has been that of preservation.

Federal efforts in land acquisition have indirectly preserved many sections of maritime forests through their inclusion in the national seashore system. Although this ownership encompasses a considerable portion of North Carolina's barrier islands, the amount of maritime forest on the true Outer Banks is limited, often representing only twenty percent of the land area (Godfrey and Godfrey, 1976). Other efforts through state agencies and quasi-public organizations such as the Nature Conservancy have been directed toward the preservation of specific stands of forest which either represent unique natural areas or have been available for acquisition or donation as State Parks or Natural Areas. Examples of such forests are found in Nags Head Woods, Roosevelt Natural Area, and Hammock's Beach State Park. At the local level, a number of coastal communities including Emerald Isle and Pine Knoll Shores have developed provisions within their regulatory codes which require some degree of protection for maritime forest vegetation during the site development process.

More recently, the North Carolina Office of Coastal Management has taken a more active approach by preparing preliminary performance standards which would be applied to all maritime forests present within designated Areas of Environmental Concern (AECs) (Brower, 1980). The standards, though carefully developed, would be limited in extent to AECs, very few of which have been designated. Alternatively, if through the formulation of a state policy on maritime forests, all forests were given AEC classification similar to those imposed on estuarine areas, an unrealistic hardship would be placed on the private landowner. Thus, at present, the state's unofficial policy on maritime forests is constrained by a dominant preservation tone in which only limited areas of forest might be expected to come under some protection. If it were implemented over all maritime forests, its performance standards as proposed would be too restrictive.

Considering the limited ability of preservation techniques to protect all maritime forests and the sobering thought that most privately-owned tracts of maritime forest may well be developed by the end of this decade, future strategies must certainly embrace a more flexible conservation-oriented perspective.

Interestingly, one such strategy has emerged from the U.S. Army Corps of Engineers. After years of pursuing costly and short-term structural solutions to stabilize barrier islands and protect federally-insured devel-

Figure 6. Elevated boardwalks beneath canopy limit disturbance of the maritime forest. Photo by L. Zucchino

opments (i.e., beach replenishment, groins, jetties, and bulkheads), the Corps has recently begun to entertain the concept of non-structural alternatives. The most promising alternative is an intact and properly functioning maritime forest. Efforts to investigate the land use implications of just such an approach have recently been stymied by a reluctance on the part of the Corps to become directly involved with the associated land use planning issues. The technical information amassed by the Corps is impressive and the well-conceived land planning strategies which give high priority to maritime forests represent the most progressive efforts to date by a government agency to manage the forests.

The Corps' strategy would emphasize some form of local or state regulatory control over the salt spray shear zone while managing the remainder of the maritime forest less rigorously. The mechanism which would provide this protection has not yet been fully elaborated but would necessarily require an uneasy marriage between state and local government and the private sector. Any management effort will face the problem of the large amount of forest which is privately-owned and strong local resistance to any increase in the state's regulatory role in coastal development. These constraints suggest that future efforts to protect the maritime forests will revolve around improved local ordinances and an increasing awareness by the private sector of the increased market value that a well-managed maritime forest can bring to a residential lot or development.

A reasonable approach to comprehensive planning and management for maritime forests must include a concerted effort between federal, state, and local agencies. In addition, there must be active participation by private development interests and research institutions. The Corps of Engineers should reactivate its plans for developing non-structural solutions to barrier island stabilization stressing protection of maritime forests through proper land planning. Through CAMA, the State should consider AEC designation for the salt spray shear zone of the forest, provided that standards of performance can be developed which will protect the integrity of the forest without depriving the private landowner of a reasonable use of the land. State agencies and private consultants could provide expertise and technical assistance to developers interested in protecting the forest during development. Management of the forest outside the shear zone should be left to each local government's initiative. They should, however, be guided through CAMA to develop effective vegetation ordinances and to use proven economic incentives to encourage cooperation from the development industry and local landowners. The question remains as to whether the next several years will produce the necessary balance between coastal development interests and regulatory controls which will serve to protect sensitive and vulnerable maritime forests and allow for a reasonable integration of coastal development into the remaining forest.

REFERENCES

Au, Shu-Fun. 1974. *Vegetation and Ecological Processes on Shackleford Bank, North Carolina*. Nat. Pk. Ser. Sci. Mono. Ser., no. 6.

Bellis, Vince, 1980. Personal communication.

Bellis, Vince and Edward Proffit. 1976. "Maritime Forest." *Ecological Determinants of Coastal Area Management: Volume II -- Appendices*. Sea Grant Publication No. UNC-SG-76-05, Raleigh, NC, pp. 22-28.

Brower, David J., et al. 1980. "Proposed Standards for Development in Maritime Forest Areas of Environmental Concern." The Center for Urban and Regional Studies, UNC-Chapel Hill, NC, 22 p.

Eaton, Thomas E. 1979. "Natural and Artificially Altered Patterns of Salt Spray Across a Forested Barrier Island." *Atmospheric Environment*. 13:5.

Fussell, John O. 1978. *Bogue Banks Study*. Office of Marine Affairs, NC Dept. of Admin. and U.S. Fish and Wildlife Service. 40 p.

Graetz, K. E. 1973. *Seacoast Plants of the Carolinas*. Dept. of Ag., Soil Conservation Service, Raleigh, NC.

Natural Systems Associates, Inc. 1980. *A Vegetation, Soil and Natural Resource Management Program for Development of Bald Head Island*. Raleigh, NC 26 p.

Pilkey, O.H., Jr., O.H. Pilkey, Sr. and R. Turner. 1976. *How to Live with an Island: A Handbook to Bogue Banks, N.C.*, N.C. Dept. Nat. Econ. Res., Raleigh, N.C.

Wells, B.W. 1939. "A New Forest Climax: The Salt Spray Climax of Smith Island, N.C." *Bull. Torrey Bot. Club*. 66:634

Zucchino, Lawrence R. 1979. *Report on the West Pine Knoll Shores Land Development Plan*. Ocean Grove Associates, Pine Knoll Shores, NC. 18 p.