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NORTH KEY LARGO, FLORIDA

HABITAT CONSERVATION PLAN

STUDY COMMITTEE FINAL REPORT

SEPTEMBER 15, 1986

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HABITAT CONSERVATION PLAN

I.
SUMMARY

North Key Largo is the habitat of four species listed as endangered under the Endangered Species Act, 16 U.S.C. §§1351 et seq. -- the American crocodile, the Key Largo woodrat, the Key Largo cotton mouse and the Schaus swallowtail butterfly. Development of lands within North Key Largo may "harass, harm or kill" these endangered species in violation of the Endangered Species Act; however, section 10 of the Act provides a mechanism for the "incidental" taking of endangered species. An incidental taking permit may be issued by the Secretary of the Interior if the Secretary finds that a Habitat Conservation Plan ensures that:

1) the taking will be incidental (that is, ancillary to a principal lawful activity);

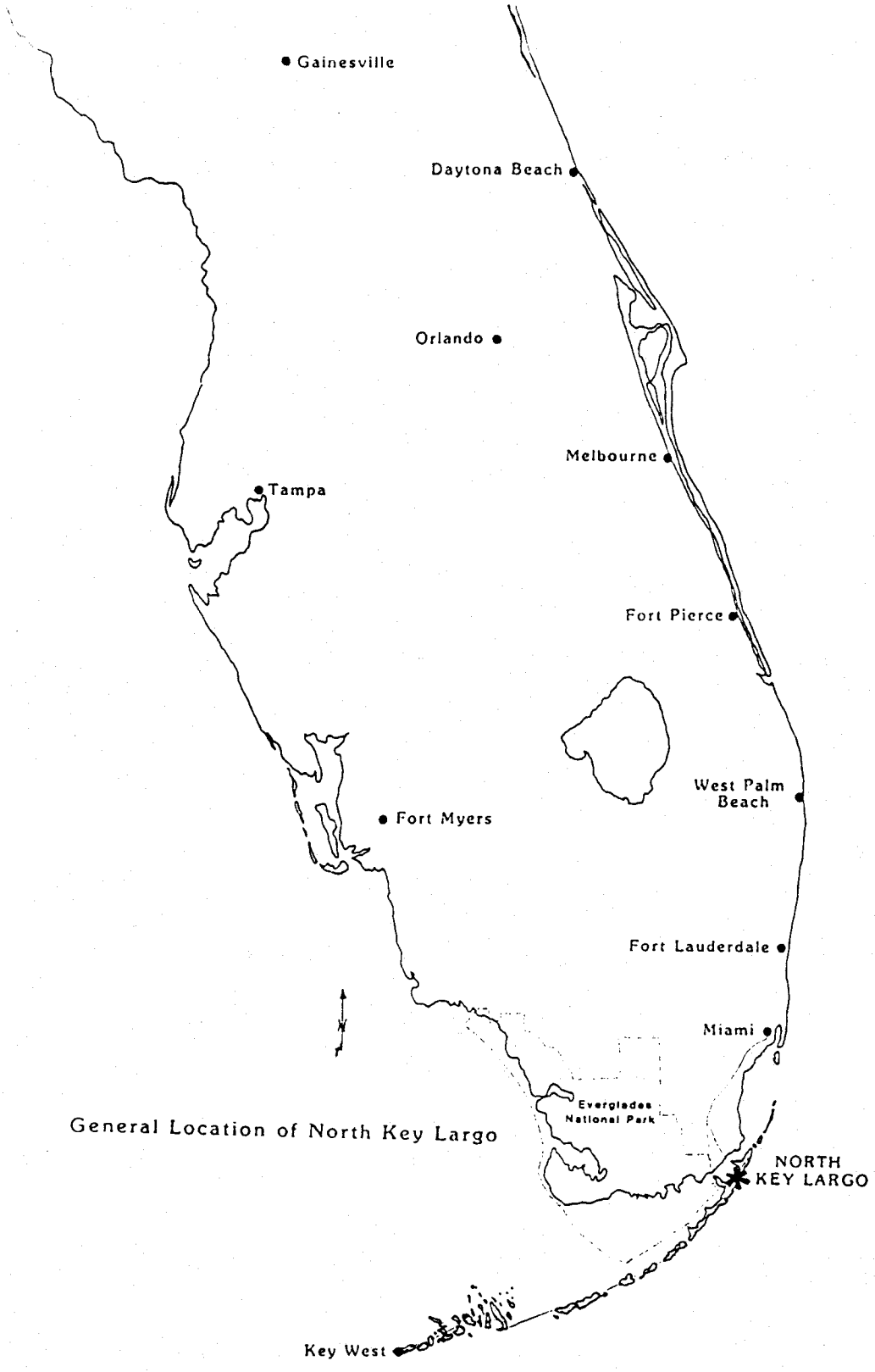
2) the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking;

3) the applicant will ensure that adequate funding for the plan will be provided; and

4) the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.

This Habitat Conservation Plan has been prepared as a means of reconciling the habitat needs of the endangered species on North Key Largo and the investment and development expectations of the owners of land in the area. Figure 1 shows the general location of North Key Largo. The area contains approximately 10,000 acres of hardwood hammock and mangrove wetland, the vast majority of which is currently in a natural state, although a significant portion of the upland on the Key was cleared for agricultural purposes in the early years of this century.

FIGURE 1: GENERAL LOCATION OF NORTH KEY LARGO



General Location of North Key Largo

Land clearing in conjunction with development on North Key Largo threatens all four species as does the establishment of a resident human population in the midst of the animals' habitat. The Key Largo woodrat, the Key Largo cotton mouse and the Schaus swallowtail are found in tropical hardwood hammocks in the area and are threatened with extirpation if their habitat is destroyed or if sufficient human activities render their habitat inhospitable. The American crocodile inhabits shallow mangrove wetlands in the area (mostly along Barnes Sound on the northwest side of the Key) and is sensitive to human presence by way of road kills, collisions with boats and reluctance to nest in the vicinity of frequent human activity.

In order for the species to survive and recover it is necessary to:

1) preserve their habitat (in sufficient quantity to accommodate stable reproductive populations) from human activity and presence;

2) limit human activities in the vicinity of the animals' habitat to those that are compatible with the survival of the species;

3) enhance the animals' habitat by implementing mitigation strategies including the elevation of existing roads, the termination of aerial spraying for mosquitos and the restoration of the functional integrity of the Dispatch Creek Slough; and

4) Implement recovery actions necessary to improve habitat quality and enhance the survival of the species.

A significant part of North Key Largo has been designated as part of the Crocodile Lake National Wildlife Refuge and is owned by the Department of the Interior or is slated for public acquisition. Figure 2 shows the boundaries of the Crocodile Lake National Wildlife Refuge. The balance of the property is owned by more than fifty private landowners and the State of Florida. The State of Florida's major holdings are shown in Figure 3.

FIGURE 2: NORTH KEY LARGO MANAGEMENT AREA BOUNDARY (WITH CROCODILE REFUGE BOUNDARY)

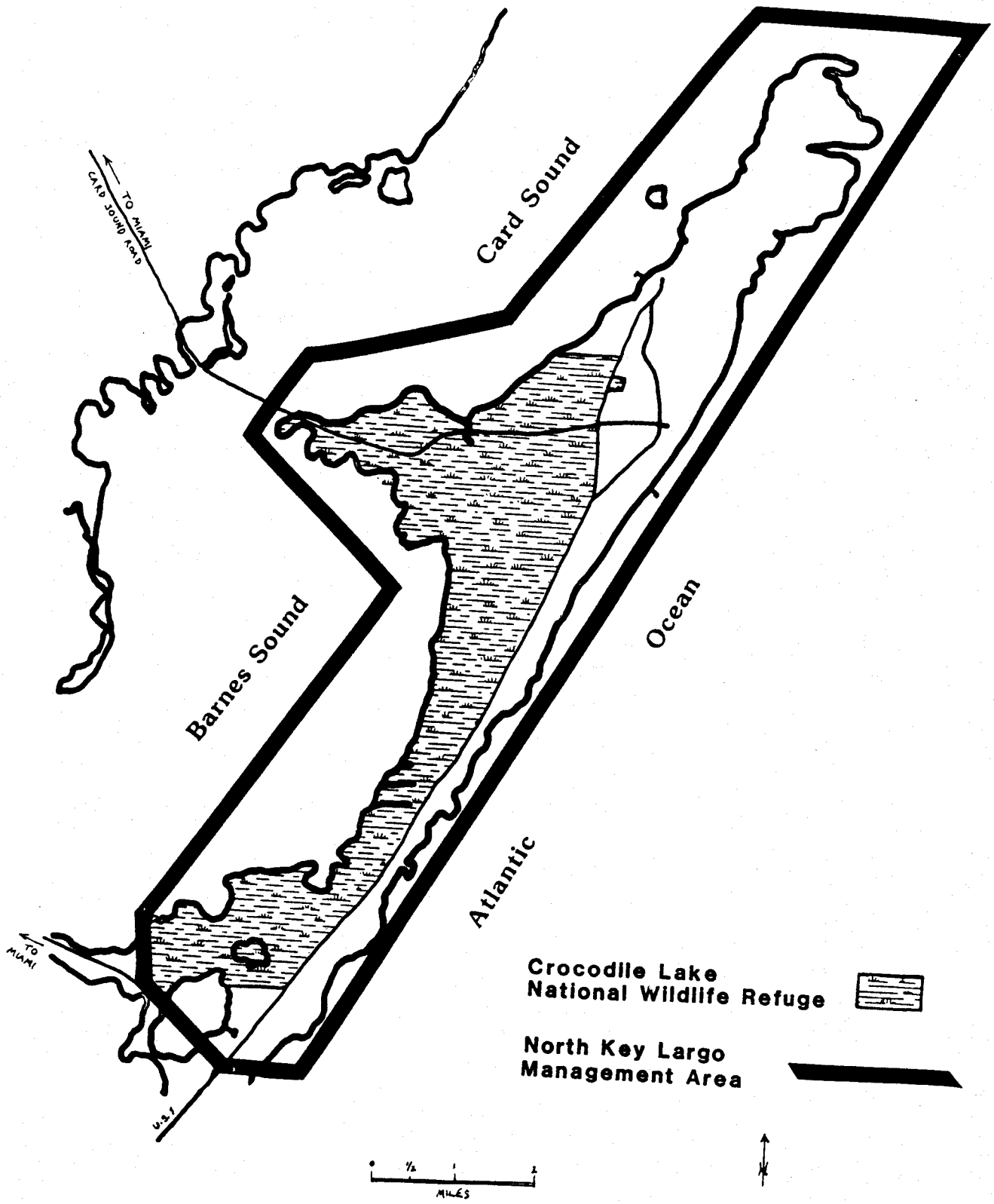
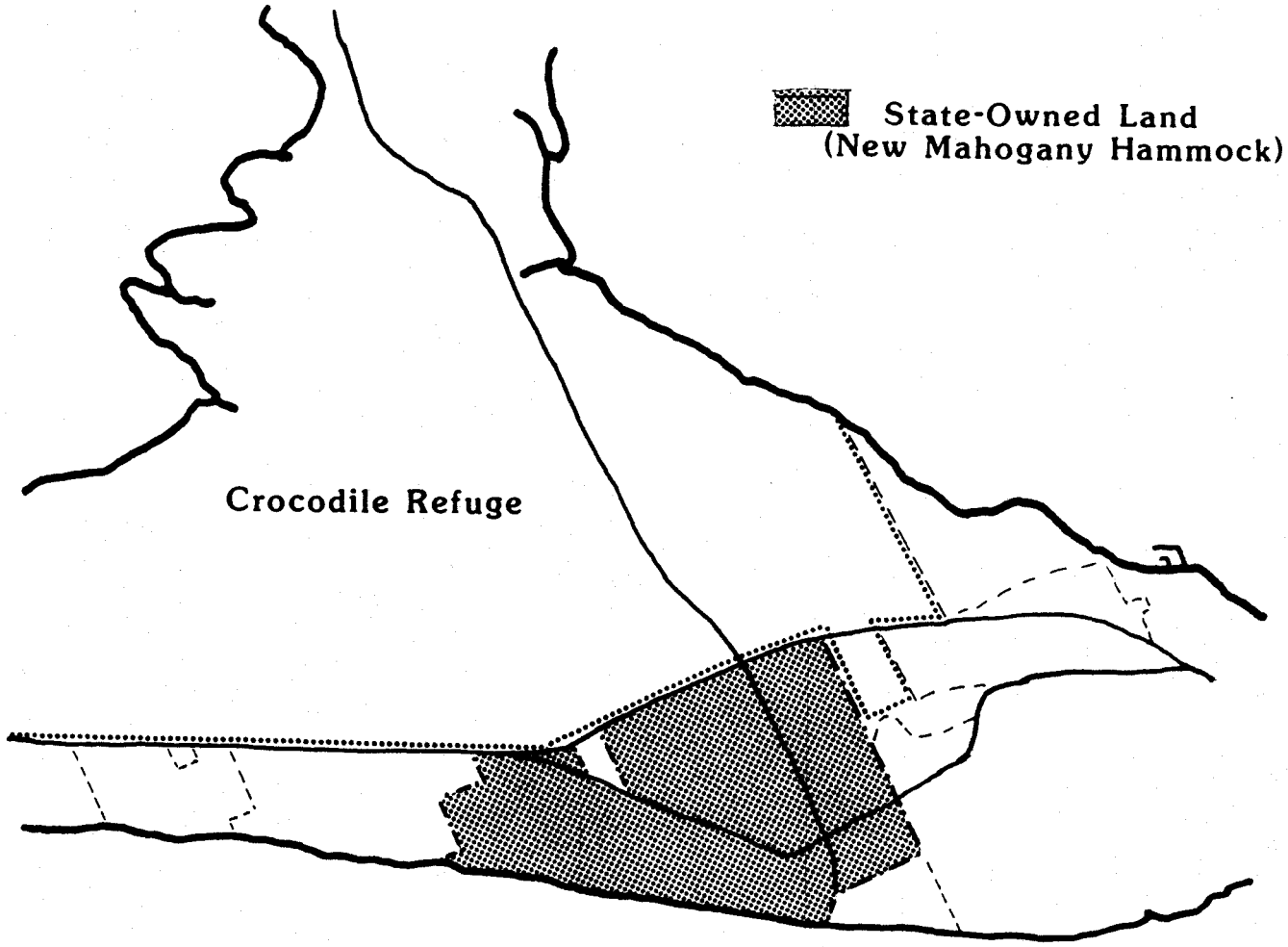


FIGURE 3: STATE-OWNED LANDS ON NORTH KEY LARGO



In 1985, Governor Bob Graham established a gubernatorial study committee for the purpose of preparing this Habitat Conservation Plan. The Committee, comprised of private landowners and their representatives, officials from local, regional, state and federal agencies with jurisdiction over or an interest in the endangered species or land use on North Key Largo and representatives of several environmental and public interest groups, met on a regular basis between September 4, 1984 and July 30, 1986 and was provided staff support services by Monroe County, Florida. The work of the Committee was financed by a $98,000 appropriation by the Congress of the United States and matching funds provided by private interests, Monroe County and the State of Florida. The study program of the Committee included a characterization of the existing natural and built environment of North Key Largo, a compilation of available information on the biology of the endangered species, an evaluation of the development capacity of the road network serving the area and an assessment of the economic feasibility of land acquisition and development. In addition, the Study Committee commissioned or arranged for further research in regard to the woodrat, the cotton mouse and the butterfly in order to confirm the biological assumptions and bases to be employed in designing the Habitat Conservation Plan.

From the assembled information, the Study Committee established a series of discrete policy statements and management assumptions. These statements and assumptions constitute the substantive basis and guiding principles for this Habitat Conservation Plan.

The Plan provides for the designation of areas of large, contiguous tropical hardwood hammock as "conserved habitat" and limits development to a series of discrete nodes. The Plan specifies the character, location and magnitude of development that is authorized within the development nodes and provides that maximum densities within the nodes can only be achieved through the use of development rights transferred from lands designated as Conserved Habitat. The Plan, however, provides that even the limited amount of development that is provided for in the Plan is to be deferred until after August 1, 1988, except for existing legally vested projects, in order to provide a reasonable opportunity to pursue the public acquisition of all land on North Key Largo.

The development authorized by the Habitat Conservation Plan will have direct and indirect impacts on the endangered species; direct impacts due to the destruction of habitat, and indirect impacts such as boat collisions, feral animals, toxic chemicals and road kills. The Plan provides specific management responses to each of the direct and indirect impacts, responses that are to be implemented through regulations imposed by Monroe County and through private covenants and contracts between landowners, interested parties and developers.

The maximum land area that could be developed under the Habitat Conservation Plan involves less than 16 percent of the total upland habitat of the endangered species and none of the wetland habitat. Moreover, study research has demonstrated that most of the hardwood hammock areas that are designated as development nodes support a relatively low density of rodents compared to population densities throughout the North Key Largo area and are located immediately adjacent to existing developed areas at the northern and southern end of North Key Largo where additional indirect effects from development are unlikely to be significant. The impact of the development on the Schaus swallowtail is problematical. The butterfly's distribution on North Key Largo is scant and the population is properly described as a remnant. Of the four locations on North Key Largo where the butterfly has been sighted during comprehensive and exhaustive surveys during the last three years only one is located within a development node, an area that is adjacent to the Ocean Reef Club/Angler's Club.

Finally, the Plan provides for a series of mitigation and recovery programs to protect and enhance the environmental values of the area and to enhance the potential for survival of the four endangered species including:

1) restoration of the historical water regime in Dispatch Creek Slough -- American crocodile;

2) elevation and culverting of the Card Sound Road -- American crocodile;

3) prohibition of aerial spraying for mosquitos -- Schaus swallowtail;

4) planting torchwood and wild lime as host plants -- Schaus swallowtail;

5) removal of roadbed for Card Sound Road extension, Old Card Sound Road and the Old State Road 905 -- Schaus swallowtail, Key Largo cotton mouse and Key Largo woodrat;

6) elimination of feral animals in conserved habitat -- Key Largo cotton mouse and Key Largo woodrat;

7) establishment of a hammock corridor across the Carysfort development node -- Key Largo cotton mouse and Key Largo woodrat; and

8) removal of trash and exotic species -- Key Largo cotton mouse and Key Largo woodrat.

The planning approach established in this Habitat Conservation Plan provides benefits to all parties involved in the process. The Federal government achieves endangered species protection, the State of Florida achieves protection of a valuable habitat area, Monroe County accepts a limited level of additional burden on their capital facilities while receiving tax dollars in return, and the landowners' expectations are achieved through development and the allocation of transferable development rights.

II.
PURPOSE AND OBJECTIVES

As set forth in the Governor's Executive Order, the purpose of the Habitat Conservation Plan ("HCP") Study Committee was to:

> formulate an agreement between the participating entities and interests concerning anticipated development in the North Key Largo area and a general environmental protection plan for the same area.

The agreement was necessary, the Executive Order stated, in order to:

- ensure adequate planning and guidance for growth and development in North Key Largo.
- reconcile conflicts between the pressures of growth and conservation and to balance environmental protection and economic concerns in North Key Largo.

III.
HISTORICAL OVERVIEW

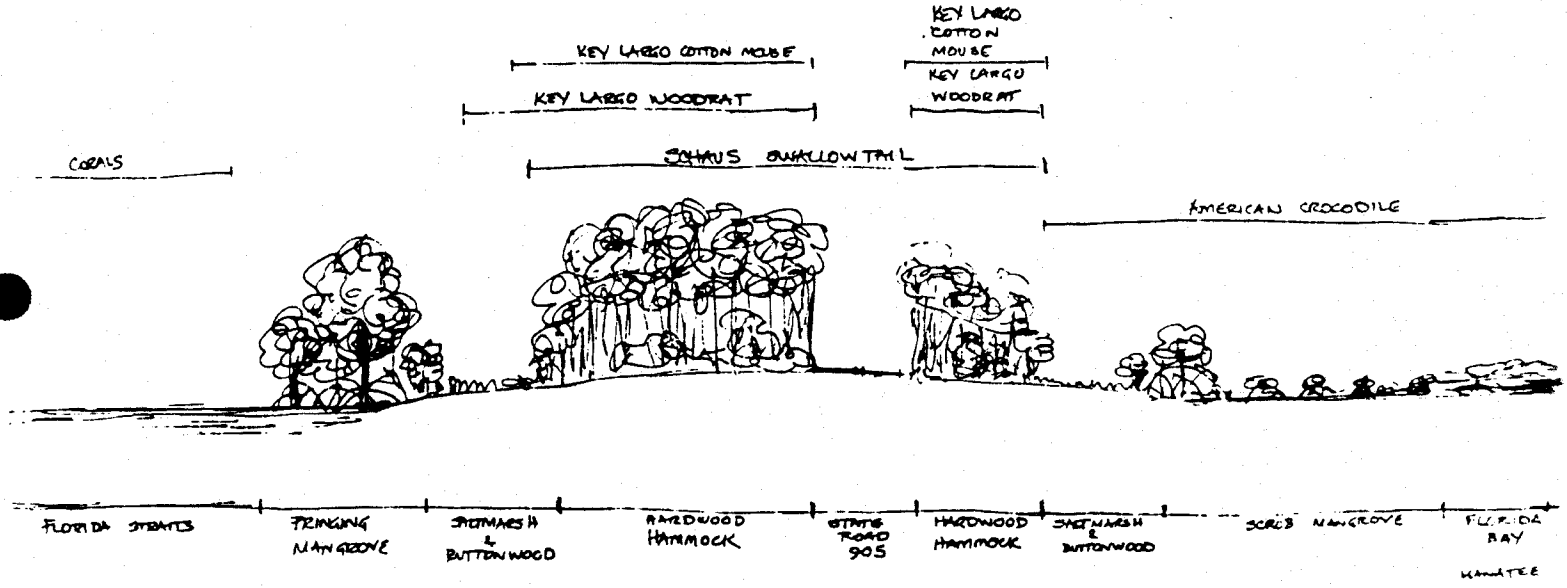
Key Largo is the northernmost of the Florida Keys and is the locus of the two roads that connect the Florida mainland to the Keys. What is commonly known as "North Key Largo" is the area northeast of the intersection of U.S. 1 and State Road 905. (See Figure 2)

The Florida Keys is an elongate, arcuate chain of low-lying islands that extend from the southeastern tip of the Florida peninsula westward to the Dry Tortugas. The Upper Keys (known as the Coral Reef Keys) are a linear chain of islands made up of limestone coral reef, a fossil coral reef whose main structure is a network of coral heads with intervening spaces filled

with detrital reef material. Key Largo limestone is a very porous coralline limestone that is riddled with solution fractures and voids allowing for the ready passage of water, a fact that results in the rapid loss of infiltrating fresh waters so that the area has very little subsurface fresh water.

The climate in the Florida Keys is subtropical, with a mean temperature of 76 degrees and 30-45 inches of rainfall each year, most of which falls during the wet season from May to October. Figure 4 is a cross-section of North Key Largo from the Atlantic Ocean/Florida Straits to Barnes and Card Sounds that shows the environmental units found on the Key. At the Atlantic/Florida Straits edge is a fringing mangrove forest which runs along the coastline, interrupted only by areas that have been previously disturbed during dredge and fill operations. The mangroves in this unit have a canopy height of 20-30 feet and serve as an effective windbreak for the upland hardwood hammocks from the prevailing southeasterly winds. Landward of the fringing mangrove unit is a transitional habitat dominated by salt marsh and buttonwood. This habitat varies from a few feet to over 600 feet wide and is subject to periodic tidal inundation. The most landward portion of this habitat contains diverse flora that reflect the proximity of the adjacent tropical hardwood hammock, the natural upland environmental unit on North Key Largo. The flora of the hammocks is derived from tropical species of the West Indies and exists on a soil made up of partially decomposed organic matter resting directly on a porous limestone substrate. This layer of organic material is critical to the maintenance of a tropical hardwood hammock and is protected from desiccation by the closed canopy and the profile of the hammock that deflects sea breezes. On the Sound side of the hammock is either a narrow transitional habitat or a scrub mangrove area that is dominated by "spider mangroves" of 3-6 feet in height. The mangrove areas are inundated by daily tides and are typically bordered on the sound side by a narrow band of fringing mangroves.

FIGURE 4: SCHEMATIC CROSS-SECTION OF NORTH KEY LARGO HABITATS



Schematic Cross-section of North Key Largo Habitats

In the early part of this century, a substantial part of North Key Largo was cleared for agricultural purposes. Over one-half of the hammocks in the study area had been cleared or significantly disturbed as late as 1940. (See Figure 5) Much of the Key was cleared for citrus groves, especially limes, as reported in The WPA Guide to Florida, originally published in the 1930's:

> ...lime groves border the highway, with wild tamarind and other hardy trees as windbreaks. The groves, haphazardly planted, are not always recognized by those familiar with the straight rows of trees in citrus groves farther north...The tree flourishes in leaf mould, thin soil, or equally well in rock crevices.

The earliest available air photos of the area (taken from a blimp in the 1920's) show scattered groves throughout the Key, with the greatest concentration near the Card Sound Bridge connection to the mainland. The old wooden Card Sound Bridge was completed in 1925. Prior to this, the only connection to the mainland was Flagler's railroad. Electricity and potable water became available in the 1940's.

By the 1960's the surrounding hammocks had re-colonized the cleared areas and were flourishing. Only minor developments (the southern-most subdivisions and the U.S. Government lands) were in progress, and a continuous stretch of hammock existed from the SR 905/US 1 intersection northeast to the Ocean Reef Club. (See Figure 6)

During the late 1970's, however, development interest in the area escalated as approvals were granted for many thousands of units. The conflict between development and environmental interests culminated in two separate proceedings. The most visible was the development approval process for the Port Bougainville and Garden Cove developments of regional impact. Another was a legal action instituted by the Audubon Society and others alleging, among other things, a violation of the endangered species act as a result of the use of federal funds to support the installation of a water line to support development that was alleged to take endangered species on North Key Largo.

FIGURE 5: NATURAL VEGETATION OF NORTH KEY LARGO IN 1940

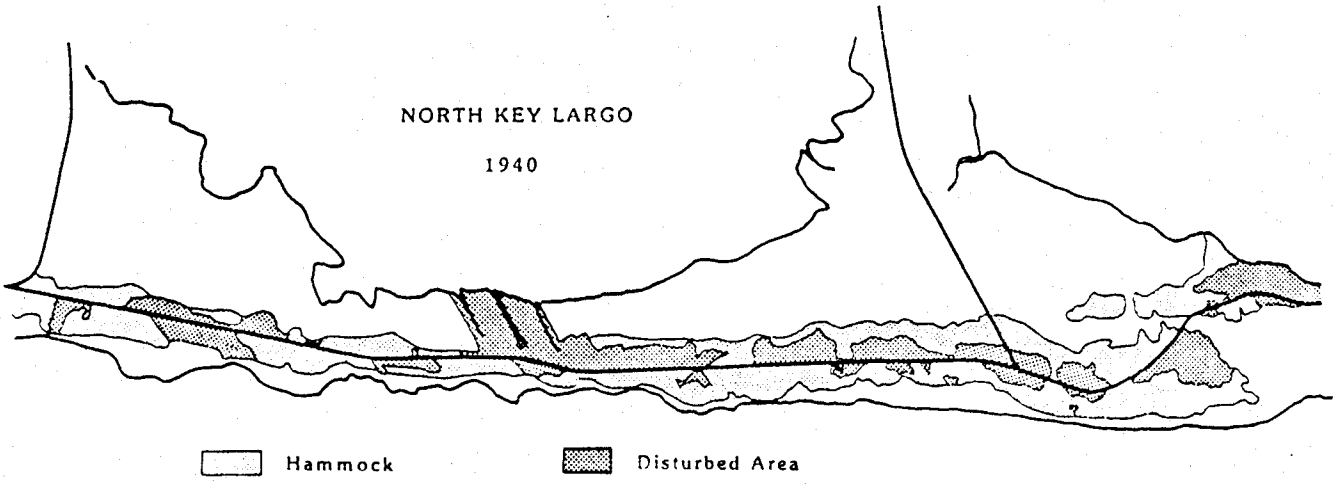
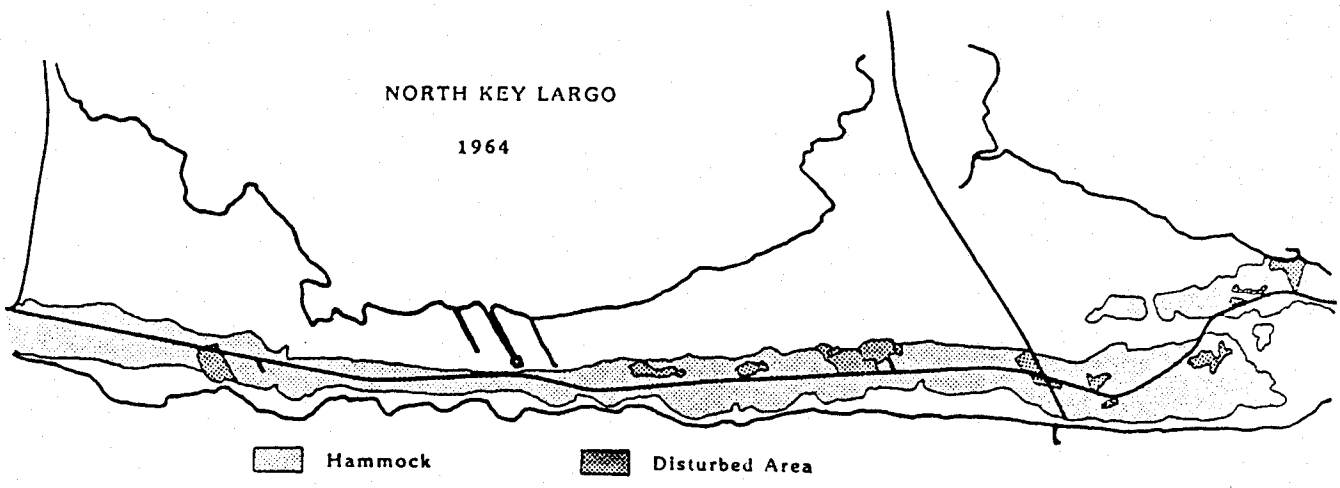
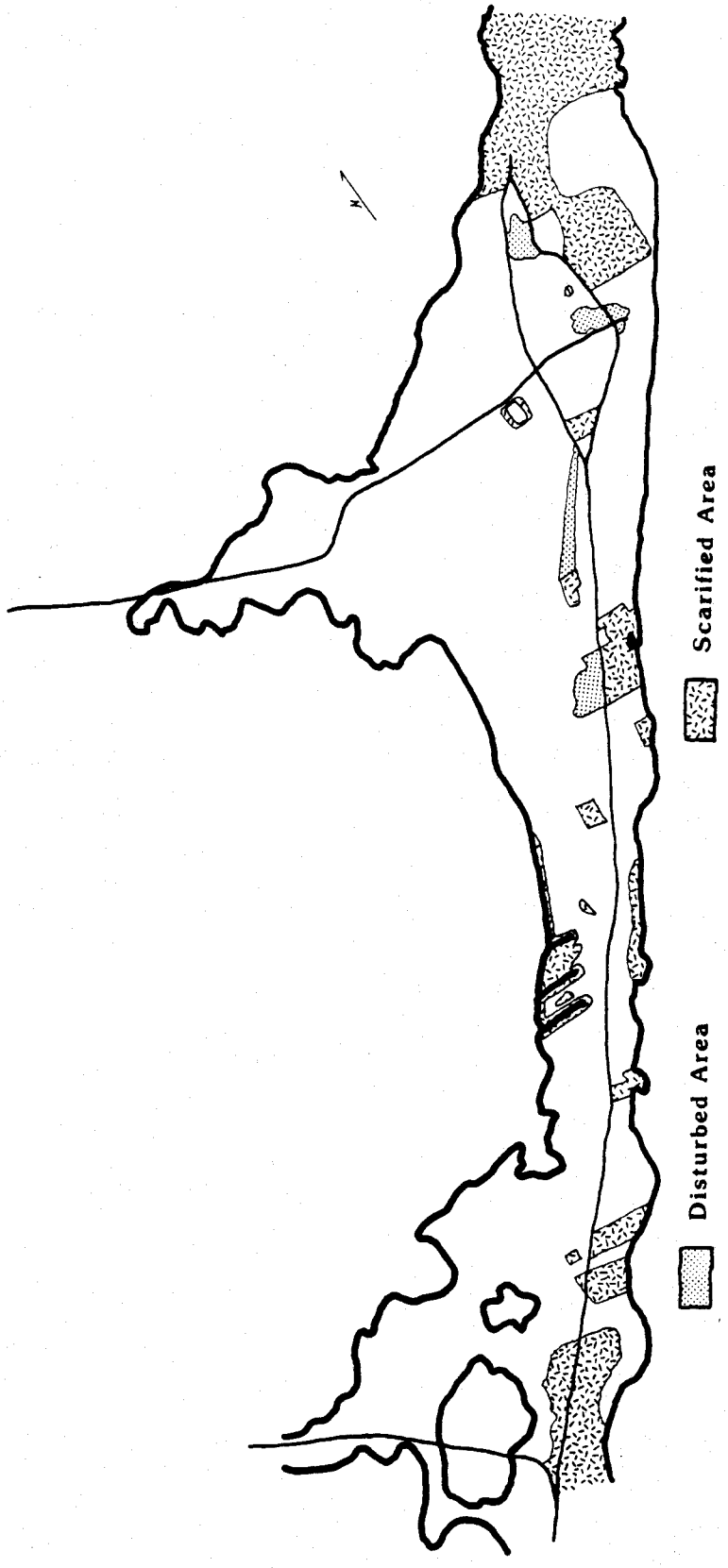


FIGURE 6: NATURAL VEGETATION OF NORTH KEY LARGO IN 1964



Notwithstanding the strong interest in development in North Key Largo, relatively little development activity has actually taken place outside of the Ocean Reef Club. The Carysfort site, which was cleared more than a decade ago, has a large deep water marina, however, repeated attempts to develop the property have failed. The site is mostly unimproved and is currently used as a campground. The area is scarified with only a few mature trees left standing as landscape material. Immediately north of Carysfort is Madeira Village, a 36 lot subdivision. To the south of Carysfort is a 25 acre site that was cleared for the Key Largo Beach and Tennis Club, a project that has not proceeded. Further to the south is Ocean Forest, a 130 acre site that has a dredge and fill marina and approximately 40 acres of scarified land. Numerous proposals for development of the site have been considered during the last fifteen years, however, there are no on-site improvements other than the marina channels. To the south of Ocean Forest are two small subdivisions, Nichols/Post and JHT, that have been previously partially cleared. Further south are three more subdivisions -- Knowlson Colony, Gulfstream Shores and Ocean Reef Shores -- all of which have been scarified in preparation for development. Finally, at the southern edge of the area is Port Bougainville where substantial clearing and excavation of fill have been carried out in preparation for development, although only 44 dwelling units and a marina building have been constructed. Figure 7 shows the location of each of the disturbed or developed areas on North Key Largo.

FIGURE 7: DISTURBED AND DEVELOPED AREA ON NORTH KEY LARGO



IV.
PLANNING AND MANAGEMENT POLICIES AND ASSUMPTIONS

The Habitat Conservation Plan is based on the following biological and management policies and assumptions:

1. that the North Key Largo hardwood hammocks and in particular mature hardwood hammocks with high, continuous canopies are vital habitat for the Key Largo woodrat and Key Largo cotton mouse;

2. that the limited distribution of the Key Largo woodrat and Key Largo cotton mouse is attributable, at least in part, to factors other than habitat destruction south of the intersection of U.S. 1 and SR 905;

3. that the Key Largo woodrat and the Key Largo cotton mouse are distributed throughout North Key Largo and inhabit a range of habitat types including all successional stages of a tropical hardwood hammock;

4. that the Key Largo woodrat is sensitive to displacement by aggressive, introduced rodent species such as the black rat;

5. that the Key Largo woodrat uses a variety of features other than stick nests for nesting and resting purposes;

6. that feral animals (particularly cats and dogs) have an adverse impact on the Key Largo woodrat and the Key Largo cotton mouse;

7. that historical clearing of tropical hardwood hammocks on North Key Largo has not resulted in the extirpation of the endangered species, although the distribution and density of animal populations has been adversely affected by clearing. The animals appear to survive isolated clearing provided that no significant disturbance as a result of human presence is established in the immediate vicinity and there remains mature, closed canopy hammock adjacent to the cleared area;

8. that various successional stages of tropical hardwood hammocks are quality neutral over time in terms of habitat for the Key Largo woodrat and the Key Largo cotton mouse because the successional stages support animal populations and if maintained will become a mature, closed canopy hammock;

9. that isolated hammocks of limited size have less habitat value for the woodrat and the cotton mouse than larger contiguous hammocks;

10. that the Schaus swallowtail is sensitive to aerial spraying of insecticides during at least larval and flight stages and that mosquito spraying has been a major factor in the decline of the butterfly and its reduced distribution;

11. that the Schaus swallowtail is dependent upon the emergent foliage of torchwood and wild lime as a host plant for egg and larval stages;

12. that the behavioral patterns of the Schaus swallowtail attracts the butterfly to the sunny edges of hammocks (for example, along roadways) during flight periods;

13. that the Schaus swallowtail can be captively bred for reintroduction into suitable habitats;

14. that abandoned roads, if managed for new growth of torchwood and wild lime and closed to general vehicular traffic, would provide extensive habitat opportunities for the Schaus swallowtail;

15. that the overall habitat value of North Key Largo will be enhanced in functional integrity if the Dispatch Creek Slough is restored to its historical character.

16. that the American crocodile is found in the Dispatch Creek Slough south (or east) of State Road 905;

17. that the state-promulgated Principles for Guiding Development call for the preservation of tropical hardwood hammocks to the maximum extent practical under the law;

18. that scarified and disturbed lands will, through natural succession, restore themselves to mature tropical hardwood hammocks provided that exotic plant species are prevented from establishing themselves;

19. that the large contiguous hammocks lying north of Carysfort and south of the Northern Node properties and the Ocean Reef Club, and lying south of Carysfort and north of Ocean Forest represent principal habitat areas to be preserved and maintained as woodrat, cotton mouse and swallowtail habitat;

20. that canal and basin depths greater than six (6) feet are undesirable because of poor flushing and water quality;

21. that the public interest may be served by the establishment on North Key Largo of a northern accessway to John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary as a part of an overall management program for the Park and the Sanctuary;

22. that development of lands immediately adjacent to the developed areas at the Ocean Reef Club/Angler's Club and Port Bougainville ends of the Management Area is preferable to the development of lands that lie in between the two in terms of limiting additional environmental impacts from development

23. that development on North Key Largo should be directed towards lands that are scarified or disturbed and away from lands that are in a natural state or in a state of succession toward a tropical hardwood hammock;

24. that to the maximum extent appropriate under state and federal regulations concerning marina siting and dredge and fill, development should be located at or adjacent to existing water access sites;

25. that increased traffic on SR 905 will increase the number of road kills of endangered species and the probability of forest fires during the dry season;

26. that the development contemplated in this plan can be accommodated by the existing configuration of SR 905 provided that such units are clustered at discrete nodes;

27. that the long term conservation of the natural resources of North Key Largo depends in part upon a public education program that informs the general public of the environmental character and sensitivity of the area;

28. that access to the John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary must be strictly controlled to prevent over-use of the reef and damage to the reef from boat operation and anchoring;

29. that the lands located within the designated boundaries of the Crocodile Lake National Wildlife Refuge will be acquired by the U.S. Fish and Wildlife Service;

30. that North Key Largo is effectively surrounded by lands that are owned or operated by public agencies for conservation and recreation purposes;

31. that the conservation of North Key Largo would be advanced by acquisition of all lands in North Key Largo and a program of coordinated management that is adequately funded;

32. that the implementation of a Habitat Conservation Plan depends upon the existence of legally binding assurances between public and private entities with jurisdiction over, ownership of, or any other interest in North Key Largo;

33. that the successful implementation of the Habitat Conservation Plan will, at least in part, depend upon funding from private and local sources;

34. that whether all or only a portion of the lands in North Key Largo are acquired for conservation, adequate funding for the management program is essential to achieving the goals of a Habitat Conservation Plan;

35. that the HCP will provide a mechanism for funding and implementation of Recovery Plans for North Key Largo endangered species;

36. that the Habitat Conservation Plan will be implemented, in part, by land development regulations adopted by Monroe County;

37. that the further development of the Ocean Reef Club will be completed according to the master plan approved by Monroe County in 1978 subject to the provisions of all state and federal regulations and laws;

38. that Port Bougainville and Garden Cove will be developed according to the DRI development orders previously granted by Monroe County unless modified or limited by law;

39. that at this time no land between the Ocean Reef Club and Port Bougainville other than improved subdivisions are assumed to have vested rights however Monroe County has established, as a part of its comprehensive plan, a procedure for establishing vested rights;

40. that the maximum development capacity of all lands between the Ocean Reef Club/ Angler's Club on the north and the Port Bougainville D.R.I. on the south is 3,500 residential dwelling units; and

41. that the allocation process will provide first for any legally vested rights in the area, and then allocate the remainder

to undeveloped lands according to their relative value;

V.
THE HABITAT CONSERVATION PLAN

A.
General

The North Key Largo Habitat Conservation Plan has been prepared for the purpose of ensuring adequate planning and guidance for growth and development in North Key Largo and to ensure that any impacts of growth and development on animals that have been listed as endangered species under 16 U.S.C. §1351 et seq. are mitigated and to ensure that growth and development will not appreciably reduce the probability of survival of the endangered species in North Key Largo.

The Habitat Conservation Plan for North Key Largo provides for, at a minimum, the preservation of the vast majority of the existing mature hardwood hammocks on North Key Largo and limits development activities to five discrete areas -- areas immediately adjacent to the Ocean Reef Club along SR 905 and the Port Bougainville project on the southeast side of SR 905 and three existing ocean access points; Carysfort, Ocean Forest and the JHT/Post Nichols Subdivision. All other lands in the North Key Largo Management Area are designated as Conserved Habitat and are to be preserved from on-site development by use of transferable development rights or acquisition of fee or less than fee interests for conservation purposes.

Under the HCP the maximum amount of hardwood hammock that could be developed assuming no lands in any development node are acquired:

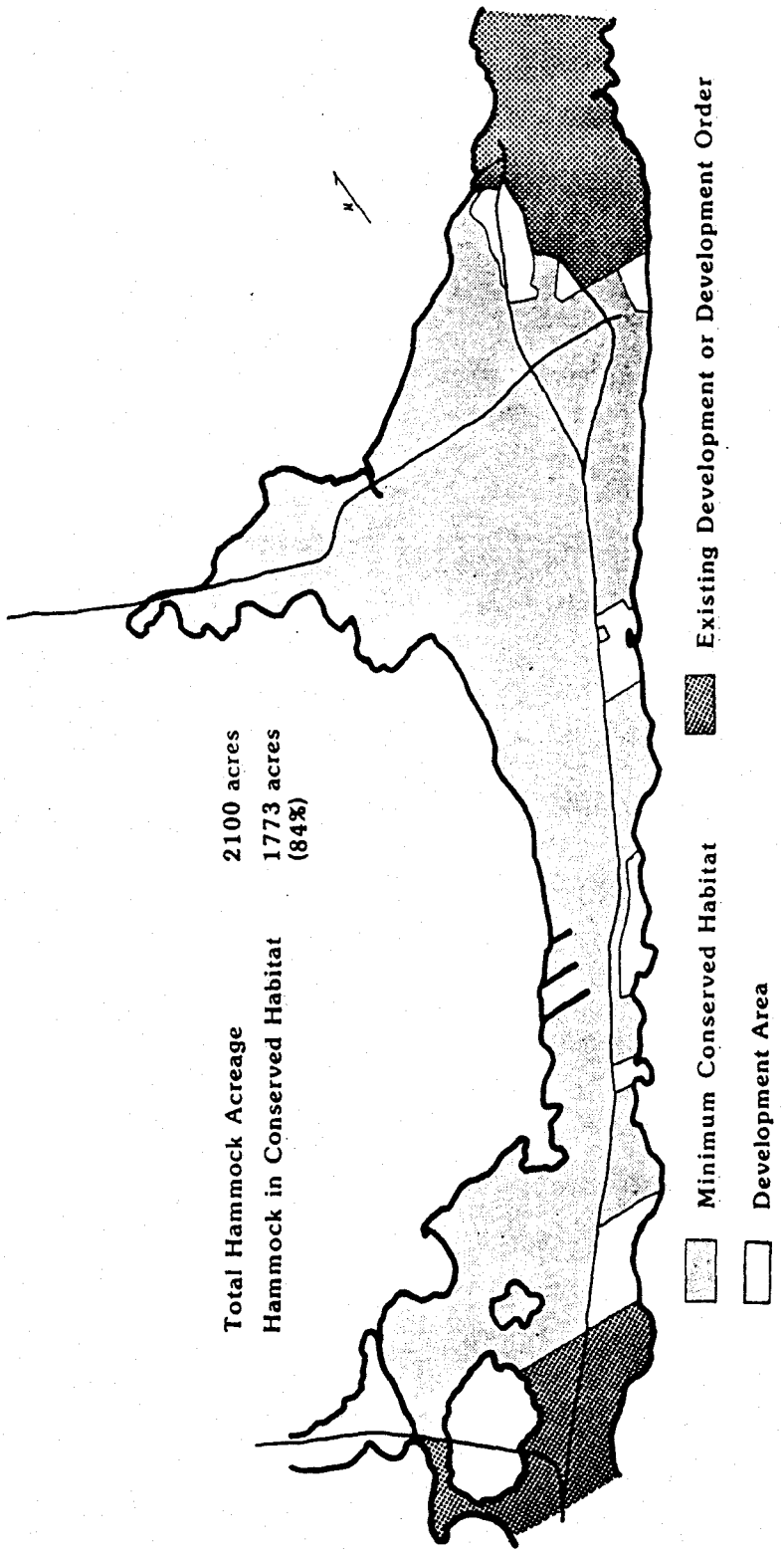
TABLE 1

Development Area	Hammock Acreage Within Development Areas
Northern Node	
Gong East and West	159
Gardner - Slough	30
Gardner - Ocean Front	50
Carysfort	
Carysfort	0
Madeira Village	0
Ocean Forest	
Harrison/Shadek*	40
Sea-to-Sound*	10
JHT/Nichols Post	2
Southern Node	
Knowlson Colony Subdivision	0
Gulfstream Shores Subdivision	0
Ocean Reef Shores	0
Bougainville North	36
Hammock Acreage within Development Areas	327 acres
Total Hammock Acreage	2100 acres

* Note: Acreage does not include hammock located in 300' buffer area.

This amounts to less than 16% of the hardwood hammock extant on North Key Largo, and the remaining hammock, when the roadbed restoration prescribed by this plan is completed, will be preserved in large, relatively intact units. Only 20% clearing of the hammocks within Development Areas will be allowed as of right, reducing the impact to under 100 acres (or 3%) lost from the total 2100 acres unless compensating mitigation strategies are implemented by node developers. Figure 8 shows the extent and distribution of hardwood hammock preserved in the Conserved Habitat. In addition to preservation of the existing hammocks indicated in Figure 8 the HCP requires the re-establishment of a 300 foot wide hammock buffer along SR 905 in the Carysfort and Madeira Village development nodes. This is expected to provide an additional 21 acres of hardwood hammock.

FIGURE 8: MINIMUM CONSERVED HABITAT ON NORTH KEY LARGO



In order to carry out the purposes of this Habitat Conservation Plan there is hereby designated a North Key Largo Management Area which includes all lands in Monroe County, Florida lying south of the Intracoastal Waterway and northeast of the southern edge of the Port Bougainville and Garden Cove developments of regional impact. The North Key Largo Management Area is depicted on Figure 2 to this Plan.

The North Key Largo Habitat Conservation Plan will be implemented through the following public and private activities:

1. Participating landowners shall grant an option running to the State of Florida or its assigns to purchase property within the North Key Largo Management Area at fair market value;

2. Public acquisition of land within the North Key Largo Management Area;

3. Regulation of the character, location and magnitude of the use of land in accordance with the substantive provisions of this Habitat Conservation Plan.

4. The execution of contracts between private and public agencies to carry out the specific management programs established by this Habitat Conservation Plan.

B.
Specific Implementation Programs

1.
Acquisition

The consensus of the Habitat Conservation Plan Study Committee was that, as a matter of public policy, the portions of the Management Area designated as Conserved Habitat on Figure 8 should be preserved. There was no consensus as to whether, as a matter of public policy, there should be public acquisition of lands outside the Conserved Habitat area. Certain members of the Committee were of the opinion that the preferred policy should be public acquisition of all undeveloped lands within the Management Area for habitat conservation and recreational purposes, while others were of the opinion that the preferred policy would allow limited development of the lands outside of the Conserved Habitat. In order to resolve these conflicting viewpoints, the consensus of the Committee was:

1. to provide an opportunity to the state and other agencies and interests to acquire, prior to

August 1, 1988, additional lands within the Development Areas; and

2. to establish as part of the plan, provisions for limited development in the lands outside the Conserved Habitat in the event such lands are not acquired.

The habitat needs of the endangered species would be served by the acquisition of all lands in the North Key Largo Management Area, including the designated Development Areas and the partially developed subdivisions in the lower third of the Management Area. In the event Development Areas are acquired, priority for acquisition should be in the following order:

1. Ocean Forest;
2. Gardner - Oceanfront
3. Gardner - Slough
4. JHT/Post Nichols Subdivision;
5. Gong properties;
6. Carysfort;
7. Madeira Village;
8. Ocean Reef Shores Subdivision;
9. The area north of Port Bougainville to the northern edge of Knowlson Colony Subdivision;
10. Port Bougainville and Garden Cove.

2.
Land Use

The Monroe County Comprehensive Plan establishes the general character, location and magnitude of land use in the North Key Largo Management Area. The Comprehensive Plan includes a complex analysis of the carrying capacity of the Florida Keys' natural and built environment and carefully allocates growth capacity to all lands in unincorporated Monroe County. That allocation provides that the North Key Largo Management Area has a future maximum development capacity of approximately 3500 residential dwelling units or residential dwelling unit equivalents. This Plan is, by policy and law, consistent with the County Plan and therefore provides for a maximum development capacity of 3500 residential dwelling units or other uses with comparable cumulative impact on the natural and built environment.

a.
Future Land Use

In order to ensure the survival of three endangered species, the Key Largo woodrat, the Key Largo cotton mouse, and the Schaus swallowtail, it is necessary to protect and preserve

large contiguous hardwood hammock areas free of trash, insecticides and feral animals. This Plan therefore provides for the preservation of a minimum of 84% of the mature and maturing tropical hardwood hammock in the North Key Largo Management Area as conserved habitat, and limits development activity to five discrete development nodes. Two of the development nodes are located adjacent to existing development at the northern and southern ends of the Management Area. The other three are scarified or partially scarified sites that have existing ocean access.

Future land use in the North Key Largo Management Area shall be limited to the following uses:

1. Conserved Habitat --
   a. wildlife management; and
   b. public utility transmission facilities.

2. Northern Node --
   a. residential dwelling units;
   b. overnight accommodations
   c. marina facilities designed to serve residents of or guests residing in development in the Northern Node;
   d. commercial resort uses that are accessory to and subordinate to a destination resort.

3. Madeira Village Node -- single family detached dwellings;

4. Carysfort Node --
   a. residential dwelling units;
   b. overnight accommodations;
   c. marinas; and
   d. commercial resort or marina uses that are accessory to and subordinate to a marina or destination resort;

5. JHT/Post Nichols Node -- single family detached dwellings;

6. Ocean Forest Node --
   a. residential dwelling units;
   b. overnight accommodations;
   c. marina facilities designed to serve residents or guests residing in development in the Ocean Forest Node;
   d. commercial resort uses that are

accessory to and subordinate to a destination resort; and

7. Southern Node -- single family detached dwellings.

b.

Allocation of Development Rights

Development rights on North Key Largo should be allocated on an equitable basis to all privately owned properties as of the effective date of the incorporation of the Habitat Conservation Plan in the Monroe County Comprehensive Plan. The allocation shall first provide for any existing legally vested rights, including improved subdivisions, and then allocate units to undeveloped lands. The allocation formula is based on the variation in the value of land based on its natural character. Consistent with the capacity set for the area during the Monroe County Comprehensive Plan formulation, hammocks shall be allocated 2.0 units per acre, transitional habitats shall be allocated 0.6 units per acre, and scarified or disturbed lands shall be allocated 1.2 units per acre. See Table 2 for a summary of the development rights allocation.

Development rights allocated within the Conserved Habitat may be transferred into the Development Areas or out of the Management Area to other sites in Monroe County. Rights allocated within the Development Areas may also be transferred outside the Management Area. Under no conditions will such rights be used for on-site development within the Conserved Habitat. In addition, no development rights from outside the Management Area may be transferred into the Development Areas.

TABLE 2

NORTH KEY LARGO HABITAT CONSERVATION PLAN
ALLOCATION OF DEVELOPMENT RIGHTS

ALLOCATION FORMULA

	Land Type		
	Hammock	Transitional	Disturbed/Scarified
Dwelling Units Allocated per acre	2.0	0.6	1.2

ALLOCATION WITHIN DEVELOPMENT AREAS & CONSERVED HABITAT

Development Area	Hammock	Trans.	Upland Acreage* Scar/Dist.	Dwelling Unit Allocation*
Gong East and West	159.0	3.5	0.0	320
Gardner - Slough	50.0	4.5	0.0	103
Gardner - Oceanfront	30.0	7.0	0.0	64
Carysfort	0.0	0.0	107.0	129
Ocean Forest	74.0	19.0	13.0	175
Sea-to-Sound	17.0	0.0	0.0	34
Southern Node	36.0	13.0	0.0	80
Conserved Habitat	955.0	117.0	141.0	2150
TOTAL	1321.0	164.0	261.0	3055

* Note: Acreage and allocation subject to registered survey of property.

3.
Exotic Plant and Animal Control

a.
Plants

In order to maintain the natural function of the tropical hardwood hammocks that serve as habitat for the woodrat, the cotton mouse and the swallowtail, it is necessary to prevent the introduction and establishment of plant species that displace native plants and do not provide for the habitat needs of the

endangered animals. Schinus terebinthefolius and Casuarina spps. are two well-known invasive exotics that are easily established where natural vegetation has been cleared. Neither plant species is suitable as a host plant for the Schaus swallowtail nor do they provide the closed canopy environment that is believed to be the optimal habitat for the woodrat and the cotton mouse. In order to avoid the introduction of invasive exotic species, all landscaping installations within the North Key Largo Management Area shall be of plant material that is native to the Florida Keys or has been identified by the Monroe County Biologist as non-invasive and suitable for use in the North Key Largo Management Area.

b.
Animals

Although there is limited empirical evidence that introduced animals have direct adverse impact on the woodrat and the cotton mouse, the current distribution of these two species justifies a cautious approach to introduced animals. It is generally believed that the woodrat and cotton mouse were historically distributed to the south of the US 1/SR 905 intersection, but that growth and development has restricted the animals to the study area (and Lignum Vitae Key where they were introduced in 1972). There are a number of large undisturbed natural hammock areas south of the US 1/SR 905 intersection, and the absence of the woodrat and cotton mouse there is assumed to be attributable to factors other than land clearing, and one of those factors is very likely to be introduced animals.

The Habitat Conservation Plan therefore protects against the introduction of dogs and cats because of their potential as predators and the introduction of the black rat as a potential competitor. In order to achieve the goals and objectives of this Plan it is necessary that no person shall own or keep a cat or dog in the North Key Largo Management Area. In addition, in order to avoid the introduction of exotic rodents such as the black rat which may out-compete the woodrat, outside storage shall be strictly prohibited, including outside storage, even temporary, of refuse and waste.

4.
Insecticide Use

The range of the Schaus swallowtail has declined precipitiously in recent years and it is suspected that aerial applications of insecticide as a part mosquito control programs are a prime factor in this range reduction. Studies carried out by Dr. Thomas Emmel pursuant to a research grant solicited by the Study Committee revealed that the insecticide formulations used by the Mosquito Control District are 100% fatal on swallowtail larvae.

The Monroe County Mosquito Control District regularly sprays insecticide from low flying airplanes throughout the historic range of the butterfly except for North Key Largo, and Elliot, Old Rhodes and Totten Keys in the Biscayne Bay National Park. The coincidence of butterfly presence and the absence of aerial spraying is assumed to reflect sensitivity of the butterfly to the insecticides employed by the mosquito control district.

In addition, insecticides which reach nearshore waters, either through drift from spraying, or through run-off, threaten a significant link in the food chain of the crocodile. Crustaceans and other food sources for the crocodile are killed by many insecticides, including those commonly in use in Monroe County.

No person shall apply insecticides in the North Key Largo Management area except by local application in the immediate vicinity of human habitations. In particular, no aerial application of any insecticide shall be permitted in the North Key Largo Management Area including the areas of the Ocean Reef Club/Angler's Club and Port Bougainville and Garden Cove. In that no aerial application of pesticides will be allowed within the Management Area, disannexation from the Monroe County Mosquito Control District should be considered.

5.
Habitat Maintenance

a.
Removal of Exotics

In large measure, the ecological integrity of the North Key Largo Management Area is intact, notwithstanding significant human perturbations during the last 80 years. Indeed, as late as 1940, significant parts of the area had been cleared for agricultural purposes, but have since returned to mature hardwood hammock through natural succession. The introduction to south Florida generally and to North Key Largo of several invasive species of plants during recent years has established a seed source for plants that could eventually displace rodent and butterfly habitats. It is therefore necessary that all existing invasive plants be removed from the Management Area in order to eliminate these potential seed sources.

The following invasive exotic plants should be removed from the North Key Largo Management Area:

1. Sapodilla,
   Manilkara zapoda;

2. Brazilian Pepper,
Schinus terebinthefolius;

3. Leatherleaf,
Colubrina asiatica;

4. Australian Pine,
Casuarina equisetifolia;

5. Punk Tree,
Melaleuca quinquinerva.

All cleared areas in the North Key Largo Management Area shall be monitored for the establishment of invasive exotics and early successional plants (e.g. wild tamarind) shall be planted to stimulate natural succession. Where necessary to support natural succession, substrate modification should be undertaken.

b.
Removal of Trash

The black rat has been identified as a potential habitat competitor of the woodrat, therefore, it is necessary to eliminate trash and refuse that serve as an attractant and food source for the black rat. In addition, the accumulation of trash and refuse often leads to wildfire. All trash and refuse shall be removed from the North Key Largo Management Area.

c.
Feral Animal Removal

There are scattered populations of feral animals currently living in the Management Area. In particular, a modest cat population is extending southward from the Ocean Reef Club. Feral animals found in conserved habitat areas shall be captured and where possible removed to appropriate locations. Otherwise, feral animals should be captured and destroyed. An animal barrier should be installed along the boundary of any development which is adjacent to hammock land in the Conserved Habitat.

6.
Habitat Restoration

The construction of roads and roadbeds in the Management Area has resulted in two undesirable effects -- interruption of historical water flows and the opening up of tropical hardwood hammocks to vehicular access, with the attendant risk of forest fire, road kills of endangered species, and trash and refuse dumping. In order to restore the functional integrity of the Dispatch Creek Slough and to limit vehicular access to conserved habitat areas and to the return the roadway corridors to a

natural state it is necessary to remove selected roadbeds and to culvert or bridge active roads so as to allow the historic water regime in the Dispatch Creek Slough to be restored. (See Figure 9).

a.
Old Card Sound Road

Sections of the Old Card Sound Road bed shall be removed and the route restored to historical elevations in order to permit water flow through the area.

b.
Old 905

Old 905 shall be closed to vehicular traffic other than maintenance vehicles, the roadbed shall be removed and the route restored to historical elevations where it crosses the Dispatch Creek Slough.

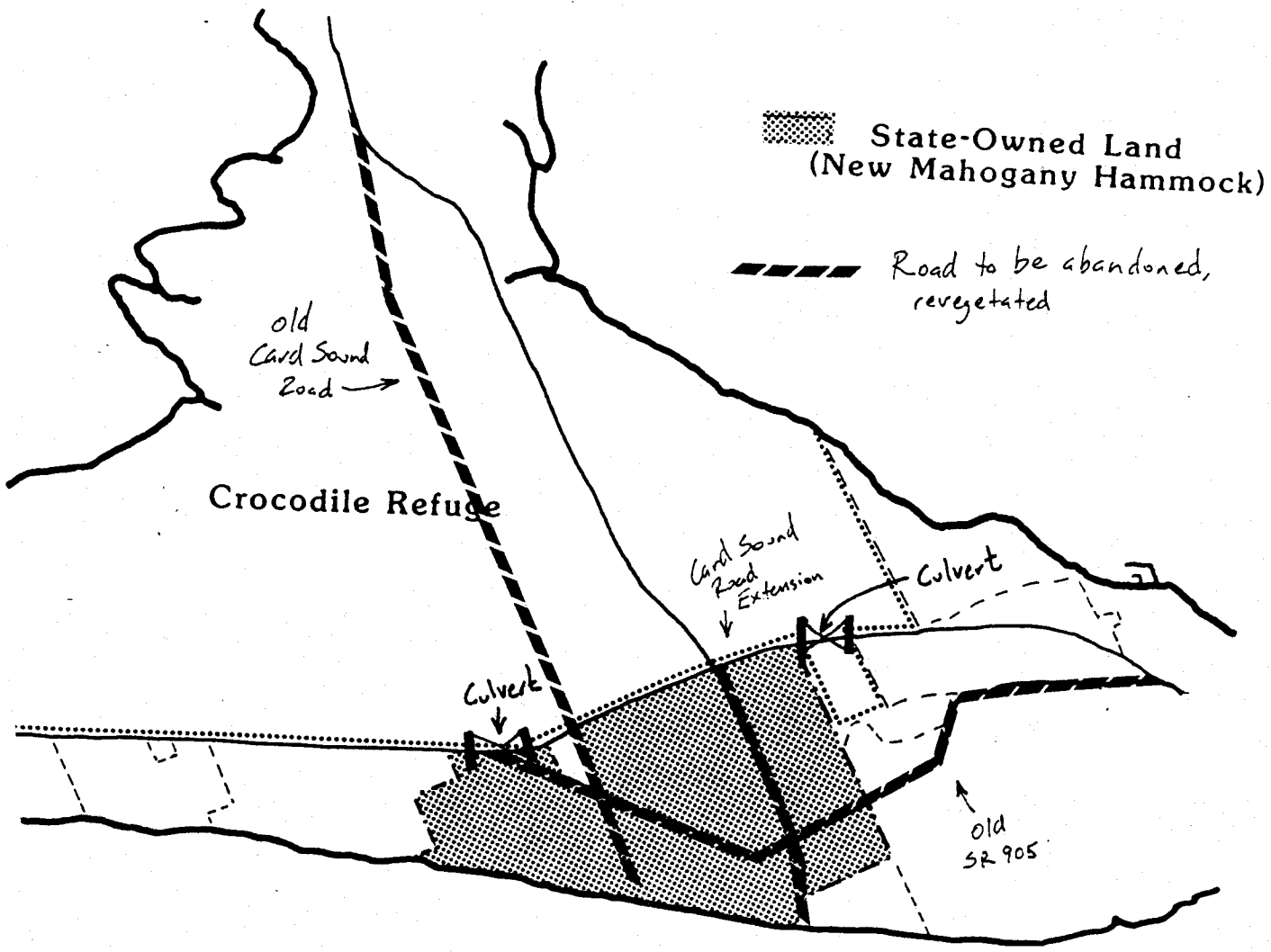
c.
Extension of Card Sound Road

The extension of Card Sound road between SR 905 and the Atlantic Ocean shall be closed, the pavement shall be removed and the route restored to its historical elevation where it crosses Dispatch Creek Slough.

d.
Dispatch Creek Slough

The natural movement of water in Dispatch Creek Slough shall be restored by the installation of culverts or bridges where SR 905 crosses the slough.

FIGURE 9: HABITAT RESTORATION - ROADBED REMOVAL



e.
Relocation of SR 905

The biology of the woodrat and the cotton mouse are such that the larger the contiguous hammock, the more functional the hammock will be in terms of enduring periodic traumas such as forest fire or hurricane. It therefore may be appropriate to consider a realignment of SR 905 between Carysfort and the intersection of SR 905 and the Card Sound Bridge Road. The northwestern limits of the hardwood hammock were previously cleared by the United States in conjunction with the government's missile complex and it may be that such a realignment would not involve any significant environmental impacts. Realignment, however, should be subject to the following considerations:

1. an environmental assessment of the proposed realignment shall demonstrate that the benefit of the realignment exceeds any adverse environmental impacts resulting from the proposed realignment; and

2. a program of restoration for the abandoned roadway, including, where appropriate, an access plan for maintenance and operation of public facilities previously constructed along or within the right-of-way of SR 905.

f.
Introduction of Host Plants

The Schaus swallowtail is dependent upon two host plants, torchwood and wild lime, and the female lays it eggs only on newly emergent foliage of these two plants. Observations of the distribution of rapidly growing young plants and the butterfly's use of the plants indicates that mid-canopy plants which have good solar access provide an optimum host plant situation. It is expected that periodic burns or other defoliation, such as by hurricane winds, fosters torchwood growth, and young torchwood is known to be an early pioneer at the edge of newly successional areas. Torchwood and wild lime along the Spite Road on Elliot Key have become a major breeding site for the Schaus and similar host plant opportunities should be established in Conserved Habitat areas. When these defoliating forces do not manifest themselves for an extended period of time, the availability of host plants is limited, suggesting that the conservation of dense, closed canopy forests may mean that new growth torchwood and wild lime should be planted along parks and abandoned roads.

A plan for planting torchwood and wild lime along paths, roadways and other natural and artificial hammock edges should be pursued in conjunction with an overall strategy to re-introduce the Schaus throughout North Key Largo. Torchwood and wild lime lost during development shall be replaced on a one-for-one basis in landscaping new development.

g.
Nearshore Waters

Water depths in dredged canals and basins that are in excess of 6 feet, such as the Carysfort basin, generally exhibit poor water quality because of inadequate flushing and limited solar penetration. In order to ensure the quality of nearshore waters it is necessary that, in conjunction with any development, all existing dredged areas be restored to depths that can be flushed. It is possible that material removed from abandoned roadways could be used as fill in such areas. All development involving existing canals, marinas or other water access facilities shall provide for improved water quality by filling in areas with depths in excess of six (6) feet.

h.
Canal Bank Modification

Crocodiles are dependent on shallow sloping banks for use as nest sites and haul-out areas. The artificial establishment of one such area on North Key Largo has proven successful, and opportunities exist to modify the canal banks on the Barnes sound side of the Key to accommodate crocodile nesting and resting activity. Modifications would include re-sloping the canal banks, providing suitable well-drained peat and sand on existing spoil banks, clearing brush on spoil banks, and creating nesting islands within the mangrove swamps. The basis for this process is laid out in the Crocodile Recovery Plan, and consultation with both the Refuge manager and the U.S. Fish and Wildlife Service must accompany any such modification.

7.
Relocation of Threatened or Endangered Plants

Any listed threatened or endangered plants located in areas designated for development shall be transplanted to suitable locations within the Conserved Habitat. A transplantation plan acceptable to the Game & Freshwater Fish Commission, the USFWS and the Monroe County Biologist shall be prepared. The transplantation plan shall contain the following:

1. A survey indicating the location, size and species to be transplanted.

2. The transplantation method to be employed.

3. A written description of the likelihood of the success of transplantation, including a description of other successful transplantations of the species proposed to be transplanted.

8.
Trapping and Relocation

Prior to the clearing of any hardwood hammock, the developer shall obtain a permit from the Game and Freshwater Fish Commission and the U.S. Fish and Wildlife Service and shall carry out "extinction" trapping of woodrats and cotton mice. All animals trapped shall be handled and relocated according to the terms of the permits authorizing the trapping.

9.
Captive Breeding and Reintroduction

The population of the Schaus Swallowtail in the North Key Largo Management Area has declined precipitiously in recent years. In 1984, a single specimen was observed in the Management Area and in 1985, only 3 individuals were observed in the Area. Although population cycles have been observed, it is unknown what factors affect Schaus populations; nevertheless it is known that larval mortality in the wild is very high (95%) as a result of a variety of factors including predation. In contrast, captive breeding of swallowtails reduces mortality to as low as 10%, indicating that a captive breeding program could establish a reservoir of genetic material that could substantially replenish the population of the Schaus in the Conserved Habitat. By manipulation of diapause, it is theoretically possible that hundreds of individuals could be returned to the Management Area in a single year.

Captive breeding, or managed wild breeding may also be appropriate for the expansion of the North Key Largo crocodile population. Successful captive breeding of other crocodilians has been carried out for conservation and commercial purposes in the past. The U.S. Fish and Wildlife Service's recovery plan for the crocodile outlines the necessary steps for such a program, however, there are no current plans to captively breed crocodiles.

10.
Public Improvements

Public improvements, such as water, sewer and electric transmission facilities, where necessary, shall be provided with minimal disturbance to the natural habitat. In addition, four types of public information signs shall be installed; one warning of crocodiles crossing both U.S. 1 and SR 905, a second along roadways during the dry season to warn of the high fire hazard, a third educating the boating public about the presence of crocodiles in Barnes Sound and a fourth educating the boating and diving public about the coral reefs and their susceptibility to damage.

Due to the threat to endangered species in the area, expansion of the existing landfill should be allowed only if all other feasible options have been explored and found unacceptable and adverse impacts on endangered species have been eliminated. Such options have already been generated for review by Monroe County, and a legislative funding package for a Keys-wide study of solid waste disposal is in place.

a.
SR 905

Between Carysfort and the Card Sound Road, opportunities for stopping along SR 905 shall be controlled to limit access to the conserved habitat, as well as to prevent the illegal dumping of refuse and trash. Consideration should be given to limiting speed along SR 905 during the flight period of the Schaus Swallowtail

In addition, one of the major threats to the hammock ecosystem of North Key Largo is that of fire. Forest fires started by careless individuals disposing of matches, cigarettes, etc., along the roadway may be the greatest hazard to successful management of the woodrat and cotton mouse population on the Key. Passive controls such as signage shall be provided in the Management Area. Other structural controls such as curbs along the roadway, and a special forest-fire-fighting team may also be appropriate.

11.
Recreation and Education

The Habitat Conservation Plan identifies acquisition of the North Key Largo Management Areas as the first priority or choice (until August 1, 1988) in reconciling the conflicting interests of landowners or developers and wildlife. The benefits of acquisition are manifold. First, landowners are given an opportunity to realize a return on their investments through negotiated payments or judicially determined just compensation.

Second, habitat areas are protected from further destruction for development purposes. Third, the public's capacity to manage lands is greater and more efficient as an owner than as a regulator. Finally, the opportunity to use the natural resources of the North Key Largo for public recreation and education purposes is enhanced by acquisition.

There is an opportunity on North Key Largo to provide a northern access point to the reefs of the John Pennekamp Coral Reef State Park and the adjacent Key Largo National Marine Sancturary. Such an access would enhance the management of the entire reef tract by relieving the pressure on the reefs at the one existing access point further down Key Largo, thereby allowing reef managers to spread recreational use over a larger area. The possibility of more active management of stressed reef areas (by closing them periodically) would be facilitated by adding more access points. Ideally, any additional access point would provide necessary on-shore support facilities including over-night accommodations as well as interpretive activities, educating the public in safe and environmentally sensible use of the reef.

The State currently owns over 733 acres of land in North Key Largo including the Dilworth tract at the Dynamite Docks. This area is designated as the Key Largo Hammocks State Botonical site. These lands are a part of the northern conserved habitat area which is the principal habitat area for the woodrat, cotton mouse and swallowtail in this Plan. The hammock is currently a preserve, and there is no program for active recreation at this site. This hammock is home to the woodrat and the cotton mouse, and would serve as a prime site for reintroduction of the Schaus swallowtail.

There is also an opportunity in North Key Largo for State acquisition to serve active recreational needs in the area. Interpretive facilities and trails within a hammock area and along a mangrove swamp would be a welcome addition to the existing State Park system in the area, fostering a greater understanding of the ecosystem of the Keys. The Management Area just north of Port Bougainville is a logical choice for such a facility. The hammocks in this area are not as mature as those hammocks further north on the Key, and therefore trails for active recreation would have less impact on the natural system here. Existing homes in the area could be held as inholdings on life-leases, or converted to tourist cabins as at Bahia Honda. This park could also serve as a land base for exploration of the abundant off-shore resources already under State management.

12.
Research and Monitoring

The publicly-owned portions of North Key Largo form a solid base for research on the Florida Keys. Study of endemic plants and animals in this area should be encouraged. Programs for reintroduction of endangered or threatened plants and animals should continue in the area, as long as there is sufficient carrying capacity to support the introduced population.

Monitoring of the status of endangered species is a necessary element of this Plan. The purpose of monitoring is to ensure that the endangered species are being adequately provided for. The program of monitoring should allow the plan to be changed based on findings throughout the process of implementation. Information regarding research, mitigation efforts, habitat enhancement, and development should be collected to gauge the progress of the plan. In order to carry out this effort, the establishment of a research facility with a field biologist and other personnel would be appropriate.

C.
Impact of Development On The Endangered Species

1.
The American Crocodile

Development authorized in the Northern Node, Carysfort, Madeira Village, Ocean Forest, and the Southern Node will not result in the direct "taking" of the American crocodile, however, increased automobile traffic on the Card Sound Road and increased boat traffic in Barnes and Card Sounds may have an indirect effect on the animal in the form of road kills, boat collisions and human disturbance during the nesting season.

The Plan provides for the elevation of the Card Sound Road with sufficient bridges or culverts to provide effective crossing opportunities for crocodiles thereby eliminating road kills as a serious threat to the animal. The Plan also provides for the installation of public warning signs indicating the presence of crocodiles and the possibility of animals crossing the road. The Plan provides that no permits for development within the North Key Largo area, except for existing legally vested projects, shall be granted unless and until public actions including the development of a funding mechanism ensure that the elevation of the Card Sound Road will be carried out within a reasonable and defined period of time. Boats departing from the Northern Node, if a marina were to be permitted, would have access to crocodile habitat, however, most recreational opportunities, such as fishing and diving, would involve a route away from the crocodile refuge. Nevertheless, the Plan provides that

any marina facilities developed in the Northern Node shall be posted with signs directing boat traffic away from the crocodile habitat and shall be subject to deed restrictions, enforceable by all parties to the Habitat Conservation Plan agreement, that prohibit the use of any such marina for the rental of water or jet ski boats and prohibit use of water or jet skis at the marina. In addition, the current program of aerial applications of insecticides, if extended to the Development Areas, would likely disrupt the crocodile's food chain, and therefore aerial application of insecticides shall be prohibited.

TABLE 3
SUMMARY OF IMPACTS

Development Node	American Crocodile Level of Impact	Mitigation Strategies To Be Employed
Gardner/Slough	**	1, 2, 3
Gardner/Oceanfront	*	1, 2
Gong East and West	***	1, 2, 3, 4
Carysfort/Madeira Village	*	1, 2
Ocean Forest	**	1, 2
JHT/Post Nichols	*	1, 2
Southern Node	*	1, 2

CONCLUSION: No Net Loss - assuming that culverting or elevation of Card Sound Road is achieved to eliminate road kills and preservation of wetland area within designated crocodile habitat.

Level of Impact Key:

* Impact from increased traffic leading to road kills

** Impact from increased traffic, human presence plus proximity to potential breeding areas

*** Impact from increased traffic, human presence, proximity to potential breeding areas and additional boat traffic near refuge waters

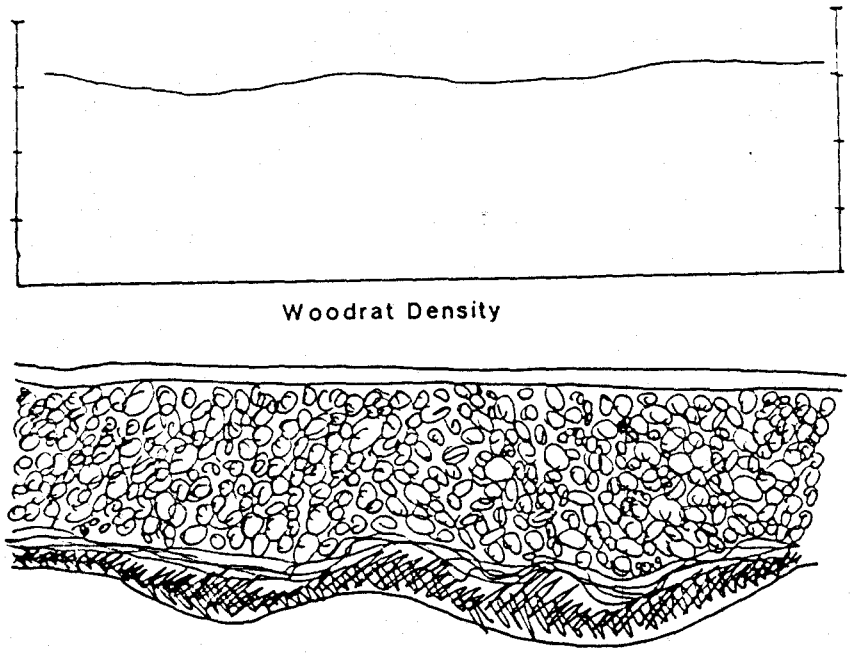
Mitigation Strategy Key:

1. Fund cutting of abandoned roads to restore historic water regime in Dispatch Creek Slough
2. Fund culverting or elevation of existing roads to allow safe crossing
3. Opportunity for donation of wetland habitat to public agency
4. Provide marina signage warning of protected refuge waters.

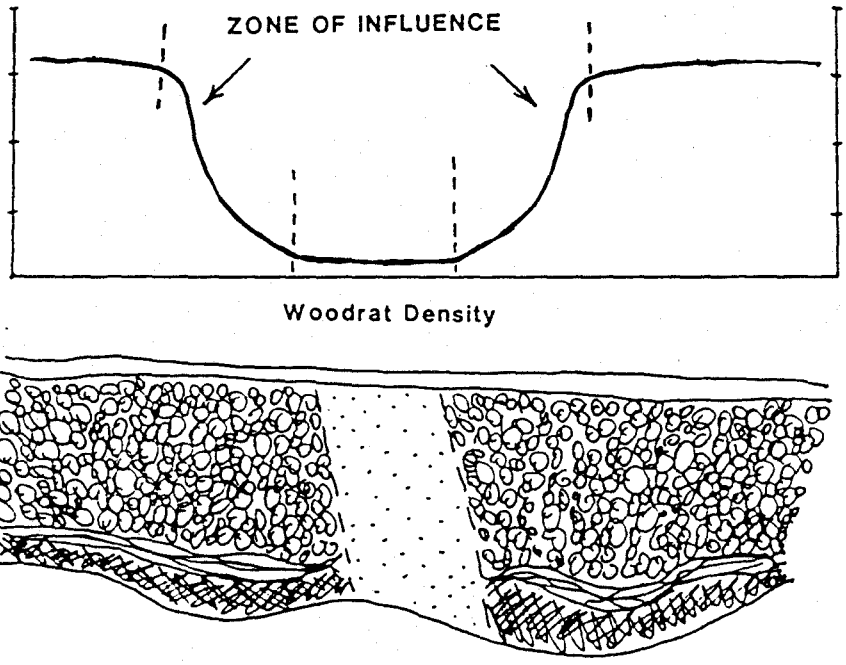
2.
The Key Largo Woodrat and the Key Largo Cotton Mouse

Development in the designated nodes will have a relatively small impact on the woodrat and the cotton mouse. Some of the developable land in the nodes is scarified land and does not currently support rodent populations. Lands adjacent to existing development support a lower density of rodents compared to median and prime habitat areas. The impact on the woodrat occurs in two ways -- direct taking of individuals as a result of development activity, and habitat degradation adjacent to the development nodes. Biological studies conducted by a team of mammalogists employed by the Study Committee demonstrated a significant difference in woodrat densities for hammocks that are adjacent to developed areas. The population data indicates the presence of a "zone of influence" effect which diminishes with distance from developed areas, and although no quantifiable determination of this effect was attempted during field work, general management needs can be identified. The concept of this "influence" is illustrated in Figure 10.

FIGURE 10: "ZONE OF INFLUENCE" EFFECT OF DEVELOPMENT ON WOODRAT DENSITIES



Before Development



After Development

The table below reports the findings of a 1986 study on woodrat densities for areas that are adjacent to existing developed areas and those which are not.

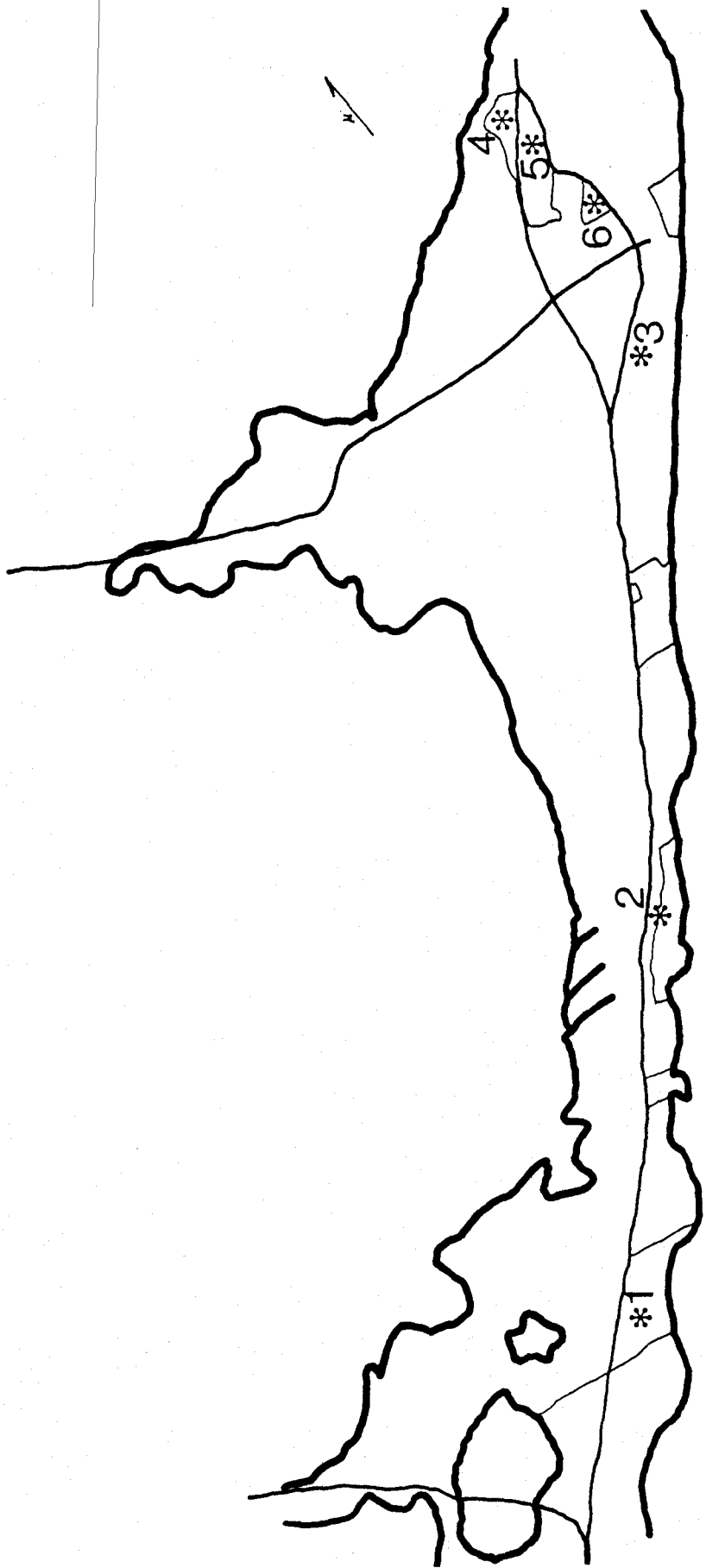
TABLE 4

Existing Woodrat and Cotton Mouse Densities

Grid Number	Woodrat Density (per acre)	Cotton Mouse Density (per acre)
Remote From Existing Development:		
1	2.79	3.84
2	2.94	18.98
3	3.89	11.70
Near Existing Development:		
4	none	1.21
5	0.57	9.92
6	2.70	8.08
Overall Average Density	3.0	8.0

Figure 11 shows the location of each trapping grid. All of the factors that affect population densities are not understood, although feral animals and increased populations of human tolerant/dependant mammals including racoons and opossums is suspected to be a major factor.

FIGURE 11: DENSITY GRID LOCATIONS - 1986 FIELD WORK



Density Trapping Grid Sites - Spring Field Work, 1986

The HCP allows for a theoretical worst-case scenario which would allow clearing of 16% of the hammocks on North Key Largo (achieved through clearing 100% of the hammock within Development Areas). The impacts on woodrats and cotton mice of that level of development are summarized in Table 5. Direct impacts are based on the loss of hammock with a density of woodrats and cotton mice equal to the most comparable grid trapped during research on the Key, as shown in Table 4. Indirect impacts were calculated based on the "zone of influence" effect in which surrounding hammocks are diminished in habitat quality as a result of human activities. These projections assume that the mandatory trapping and relocation of rodents will not avoid the loss of animals, and that mitigation activities that result from requirements for clearing beyond 20% of the hammock area will have no immediate effect.

In the worst case, the total expected loss of woodrats would be 783 animals, or 12% of the estimated 6,500 population. The impact on cotton mice would include the loss of 3,785 animals, or 21% of the estimated 18,000 population. If the strategies to eliminate indirect impacts (i.e. feral animal removal, no outside storage and exotic and trash control) are effective, the impact would be reduced to a loss of 9% of the woodrat population and a loss of 17% of the cotton mouse population.

TABLE 5

Impact on Woodrats and Cotton Mice
Worst Case Scenario

Development Area	Hammock Acreage	Woodrat Impact Direct	Indirect	Total	Cotton Mouse Impact Direct	Indirect	Total
Gong East and West	159	57	0	57	1065	58	1123
Gardner Slough	30	81	28	109	242	91	333
Gardner - Oceanfront	50	195	44	239	585	139	724
Carysfort	0	0	25	25	0	79	79
Madeira Village	0	0	25	25	0	79	79
Ocean Forest	40	118	13	131	759	101	860
Sea-to-Sound	10	29	13	42	190	101	291
JHT/Post Nichols	2	6	22	28	38	99	137
Southern Subdivisions	0	0	17	17	0	10	10
Southern Node	36	100	8	108	138	10	148
Development Area Total	327	586	197	783	3017	768	3785
Study Area Total	2,100 acres			6,500			18,000
Percentage Lost	16%	9%	3%	13%	17%	4%	21%

New habitat created by management of scarified or disturbed areas within the Conserved Habitat will provide approximately 50 acres of new hammock, expected to contain 150 woodrats and 400 cotton mice at the average density for the Study Area. When new hammock is created as a buffer along the Carysfort/Madeira Village sites, the approximately 15 acres of new hammock there would be expected to contain 45 woodrats and 120 cotton mice. This population augmentation will, however, require a substantial period of time and will not significantly affect the net population of animals for at least a decade.

These new areas would reduce the overall impact to a loss of 391 woodrats, or 6% of the estimated population, and a loss of 2497 cotton mice, or 14% of the estimated population after 20 years.

The Monroe County Comprehensive Plan limits clearing of high quality hammock to only 20% of the hammock area. This plan would allow clearing beyond 20% if mitigation is provided by the developer to offset any losses incurred through the additional clearing. Therefore, an expected scenario based on elimination of indirect impacts, clearing of only 20% of the hammock area, and new hammock created as described above has been calculated. Losses expected are shown in Table 6. The net expected impact over time would be a slight increase in the woodrat population, and a loss of 84 cotton mice, or less than 1% of the population.

TABLE 6
Impact on Woodrats and Cotton Mice

Expected Scenario (20% clearing, no indirect impacts)

Development Area	Expected Woodrat Loss	Expected Cotton Mice Loss
Gong - East and West	11	213
Gardner - Slough	16	48
Gardner - Oceanfront	39	117
Carysfort	16	52
Madeira Village	0	0
Ocean Forest	24	152
Sea-To-Sound	6	38
JHT/Post Nichols	1	8
Southern Subdivisions	0	0
Southern Node	20	28
Total	117	656
Percentage of Total Population Lost	1.9%	3.5%
New Hammock created (65 acres)	195	520
Net Impact	+78	-84

The trapping the animals for five consecutive nights before clearing any hammock area may allow for survival of many of the animals displaced by clearing. The possibility of establishing new populations of the woodrat and cotton mouse further south on Key Largo or on Elliot Key using animals trapped out of areas to be cleared should be investigated with the U.S. Fish and Wildlife Service and the Florida Game and Fresh Water Fish Commission. Such a measure would improve the long-term survival potential of the species by providing an additional discretely located population which would likely survive any catastrophic event threatening the existing population.

3.
The Schaus Swallowtail

The Schaus swallowtail butterfly has been sighted at a number of locations on North Key Largo during the last three years, however, it is evident that the population in the area has declined significantly in the last 20 years. According to known data, the development in the designated nodes will result in the direct taking of one butterfly as a result of clearing in the northern node.

According to field research conducted in conjunction with the HCP Study Committee work, the butterfly has an adult life of 6-9 days and may move several miles during its adult stage which may explain the survival of the animal. The principal threat to the butterfly is aerial spraying for mosquitos. Research, funded through a grant obtained for Dr. Thomas C. Emmel by the Study Committee, indicates that the pesticides used by Monroe County Mosquito Control District are a major factor in the decline of the butterfly. Research indicated that the formulations employed by the District have a 100% mortality rate for third-instar swallowtail larvae in application doses that are estimated to be equivalent to field applications. Moreover, preliminary data indicates that the LD50 rate (the point at which 50% of the treated animals will survive) is 1/8th the formulation currently used by the District. Assuming that mosquito spraying is in fact the major factor in the decline of the butterfly, then the survival of the species relies on the elimination of such spraying, or the use of a formula with no toxic impact on the butterfly.

Additional strategies to mitigate the impact of development on the Schaus include one-for-one replacement of torchwood and wild lime plants lost during clearing of Development Areas, revegetation of abandoned road corridors with lost plants, and further research on captive propagation. Since development under the existing Monroe County plan would likely result in the elimination of the Schaus from North Key Largo, any measures taken to cluster development and enhance habitat are net benefits to the butterfly.

D.
Impact of Development on Environmental Units

1.
Tropical Hardwood Hammock

As outlined previously, the worst-case development scenario would eliminate 327 acres of the existing 2100 acres of hammock on North Key Largo. This represents a loss of 16% of the total. However, revegetation of scarified and disturbed lands along with the provision of the Carysfort/Madeira Village buffer is expected to return 65 acres of hammock to the system. Additionally, if only 20% of the hammocks within the Development Areas were cleared, as allowed by right under the County Plan, the loss would be only 65 acres. Balancing new hammock created against a loss of 20% of the hammocks within Development Areas shows no net loss of hardwood hammock habitat over time. The protection of large contiguous hammock areas provides a net positive benefit under the plan, while protection of wildlife, trash and exotic plant control will enhance existing hammock areas.

2.
Wetlands

No development within wetland areas is allowed under the Habitat Conservation Plan. Enhancement of existing wetlands is expected through the restoration of the historical water regime in Dispatch Creek Slough.

3.
Nearshore Waters

Two major water quality issues are raised when further development on North Key Largo is considered. One is the impact of previous development activities, and the other is possible future impacts from new development. The Habitat Conservation Plan contemplates eliminating existing water quality problems caused by channels and basins with poor flushing characteristics, as at Carysfort. In addition, the Plan controls run-off from new developments, eliminating the primary threat to nearshore water quality.

4.
Coral Reefs

The biggest impact to coral reefs expected based on additional development on North Key Largo is the additional boat traffic expected. Mitigation measures contemplated by this Habitat Conservation Plan include educational and warning signage

at each marina in conjunction with the provision of anchor buoys in reef areas.

VI.
IMPLEMENTATION

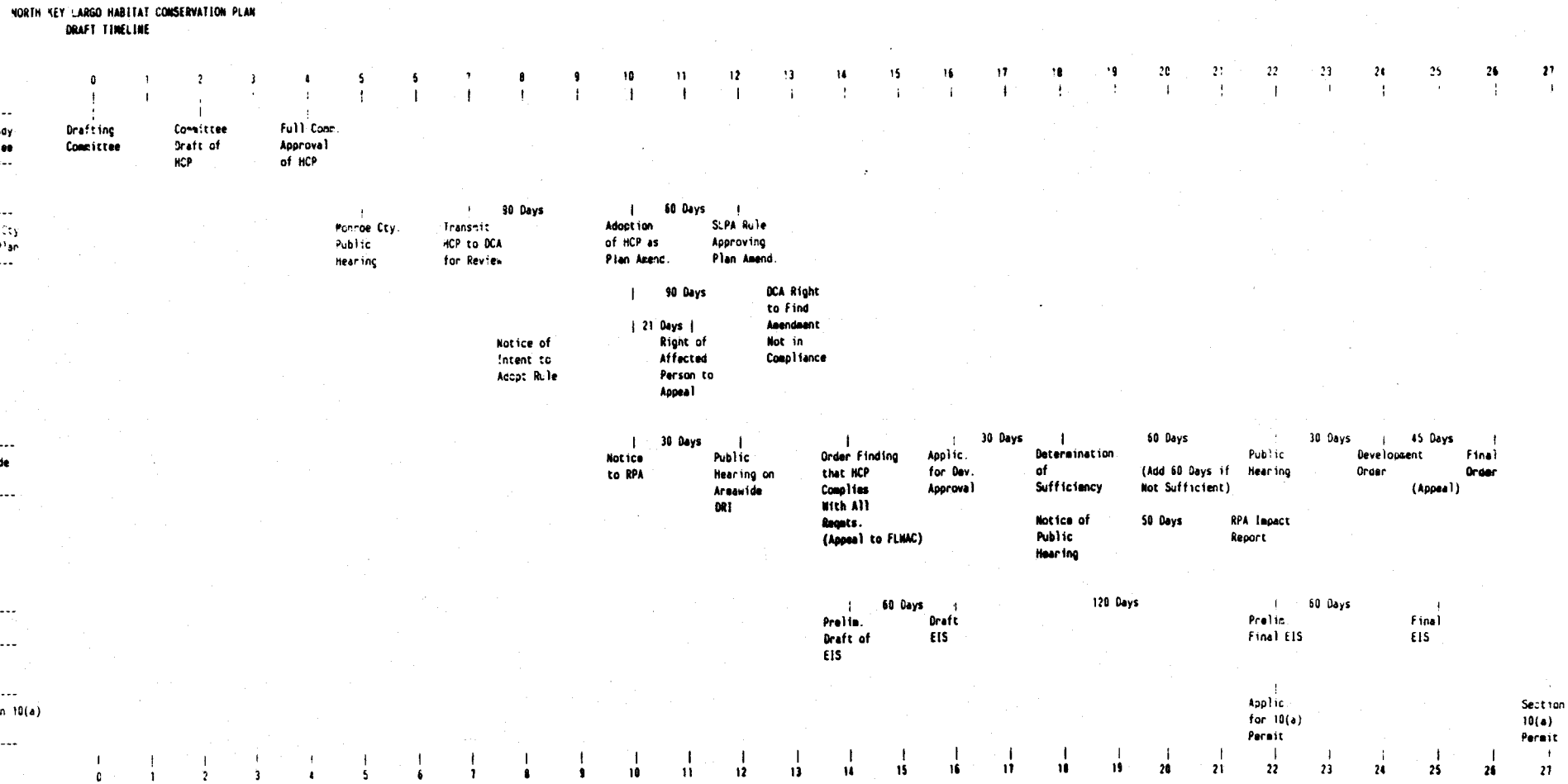
A.
General

In order to carry out the management programs established in this Habitat Conservation Plan, it is necessary to invoke both the regulatory authority of Monroe County and private covenants between landowners, public interest groups and various public agencies. The principal vehicle for implementing the Habitat Conservation Plan will be the preparation of an areawide development of regional impact (DRI) application under Chapter 380 of the Florida Statutes under which the overall plan of development will be approved by the Board of County Commissioners as an areawide DRI, with regional review by the South Florida Regional Planning Council. Figure 12 shows the time-line of how the Plan will be brought into legal force and effect as a result of the areawide DRI process. Simultaneous with the processing of the application for an areawide DRI, it will be necessary for Monroe County to adopt the Habitat Conservation Plan as an amendment to its approved Comprehensive Plan under Section 163.3161 et seq. and Chapter 380 Area of Critical State Concern. It is anticipated that Monroe County will be the applicant for the areawide development of regional impact although there is no legal obstacle to one or more landowners providing the initiative for an application for an areawide DRI. It is contemplated that the preparation of federal permitting requirements will be carried out in conjunction with the areawide DRI, and that in fact the requirements for the environmental assessment or environmental impact statement, whichever is the case, will be provided in a single volume to the maximum extent permitted under existing regulations.

No development other than development in Maderia Village, JHT, Post Nichols, Ocean Reef Shores, Gulfstream Shores and Knowlson Colony Subdivisions, Port Bougainville and Garden Cove, the Anglers Club or Ocean Reef Club shall take place until the management mitigation activities and programs required by this Plan shall have been implemented according to the terms of the governance element.

In addition to actions taken by public agencies involved in the Habitat Conservation Plan, private agencies such as the Florida Keys Mitigation Trust Fund established pursuant to court order by the Audubon Society are encouraged to continue their actions in the area which complement other actions taken under this HCP.

FIGURE 12: CONCEPTUAL TIMELINE FOR THE PERMITTING PROCESS



B.
Governance Element

1.
Purpose

The purpose of this element is to provide a procedural and substantive framework for the implementation of this Habitat Conservation Plan within the context of existing state and federal law.

2.
Adoption and Approvals

a.
In General

In order to achieve and implement the purposes and objectives of this Habitat Conservation Plan it is necessary that:

1) the Habitat Conservation Plan be adopted and/or supported, according to the individual missions and responsibilities of each governmental agency, by agencies at all levels of government in connection with their action in regard to the North Key Largo Management Area; and

2) that the Habitat Conservation Plan be incorporated into binding and enforceable assurances between public and private entities with jurisdiction over or interest in the North Key Largo Management Area.

b.
Adoption of Habitat Conservation Plan As An Amendment to the Monroe County Comprehensive Plan

The Habitat Conservation Plan shall be considered for adoption by Monroe County as an amendment to the Monroe County Comprehensive Plan under the provisions of The Local Government Comprehensive Planning Act, §§163.3161 et seq. Fla. Stat. (1985) and Chapter 380 Fla. Stat. (1985). In addition, the Board of County Commissioners shall prepare and adopt land development regulations implementing the goals, policies, objectives, critieria and standards of this Plan.

c.

Approval of the Habitat Conservation Plan As An Areawide Development of Regional Impact

The Habitat Conservation Plan shall be considered and approved by Monroe County as an areawide development of regional impact pursuant to section 380.06(25) Fla. Stat. (1985). Monroe County shall be the applicant for the development of regional impact and shall seek conceptual agency approval under section 380.06(9) Fla. Stat. (1985) concurrently with the application for development approval. The development order for the areawide development of regional impact shall be expressly conditioned upon the issuance of a section 10(a) permit by the USFWS and upon the adoption of a rule authorizing the incidental taking of endangered species pursuant to the provisions of the Habitat Conservation Plan and no development shall be carried out until and unless such permit is issued and such rule is adopted.

d.

Game and Freshwater Fish Commission

In order to carry out the development activities contemplated in the Habitat Conservation Plan, it is necessary that the Florida Game and Freshwater Fish Commission adopt a rule authorizing the incidental taking of endangered species as a part of the implementation of this Habitat Conservation Plan.

e.

Florida Keys Aqueduct Authority

In connection with the bond financing of a water pipeline supplying water to Florida Keys, the Florida Keys Aqueduct Authority covenanted with the Farmer's Home Administration not to deliver water to certain identified areas within North Key Largo so as to avoid jeopardizing the continued existence of federally listed endangered species. Because the Habitat Conservation Plan is designed to enhance the likelihood of the survival of these species, the USFWS, upon the issuance of an incidental taking permit, should amend the jeopardy finding in the biological opinion to permit the provision of water to the Development Areas. Agreements with the FKAA should expressly state that provision of water to the Development Areas subject to the provisions of this HCP is allowed, but that provision of water in Conserved Habitat areas is expressly prohibited.

f.

Florida Keys Electric Cooperative

The Florida Keys Electric Cooperative (FKEC) requested a loan from the Rural Electrification Administration ("REA") for

construction of a substation to provide increased electrical delivery on North Key Largo. Prior to approving the loan, the REA initiated a consultation with the USFWS under Section 7 of the Endangered Species Act because of the presence of endangered species in the proposed service area. The USFWS issued an opinion indicating that the proposed electric delivery system would result in development that would jeopardize the continued survival of the woodrat and cotton mouse. Because the Habitat Conservation Plan is designed to enhance the likelihood of the survival of these species, the USFWS, upon the issuance of an incidental taking permit, should amend the jeopardy finding in the biological opinion to permit construction of the electrical substation if it is necessary to serve the expected units in the Development Areas and the FKEC and the REA should revise their agreements so as to permit electrical delivery to development areas subject to the provisions of this Habitat Conservation Plan, and to expressly prohibit the provision of electrical service to the areas of Conserved Habitat for any purpose not authorized by this Habitat Conservation Plan.

g.
Issuance of Permits by the U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers has permit jurisdiction under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899 with respect to the dredging and filling of waters of the United States. The Habitat Conservation Plan contemplates limited dredging and filling of some waters of the United States and therefore participating landowners shall be required to secure such permits from the Corps.

h.
Issuance of Permits by the USFWS

The USFWS has permit jurisdiction with respect to the incidental taking of endangered species under the Endangered Species Act. In order to implement this Habitat Conservation Plan, it is necessary that the USFWS issue a permit pursuant to Section 10 of the Endangered Species Act to Monroe County, to incidentally take individuals of endangered species in accordance with the provisions of the HCP. An environmental impact statement will be prepared covering the proposed action and consultation conducted under Section 7 of the Endangered Species Act to confirm that the proposed actions will not jeopardize the continued existence of the federally listed endangered species.

i.

Issuance of Permit by Department of Environmental Regulation

When reviewing dredge and fill permit applications for proposed projects within the area addressed by the North Key Largo Habitat Conservation Plan, the Department of Environmental Regulation will take this Plan into consideration when balancing the public interest concerns as required by Section 403.918(2), Florida Statutes.

j.

Conserved Habitat and Public Recreation Area Operating Agreement

The various governmental agencies holding or managing lands within the North Key Largo Area should enter into an agreement which provides for the management and operation of the Conserved Habitat ("Conserved Habitat and Public Recreation Area Operating Agreement").

The Conserved Habitat and Public Recreation Area Operating Agreement should provide for the following:

a. Construction of improvements needed for wildlife management purposes;

b. Operation, maintenance and repair of infrastructure in the Conserved Habitat;

c. Restrictions on the use of Conserved Habitat and the Public Recreation Areas to assure that they will be used in accordance with the Habitat Conservation Plan;

d. Restrictions on the use and operation of the Public Recreation Areas to ensure the effective implementation of the HCP; and

e. The sharing of the costs for the operation and management of the Conserved Habitat and the Public Recreation Areas.

k.

Habitat Conservation Plan Agreement

In order to provide the assurances and undertakings that are necessary to implement this Habitat Conservation Plan, Monroe County, The Department of Community Affairs, Game and Fresh Water Fish Commission, USFWS and private landowners desiring to be permitted to develop under the expected Section 10(a) permit, and

participating organizations should enter into a Habitat Conservation Plan Agreement.

The Habitat Conservation Plan Agreement shall provide for the following:

a. Provision for and assurances regarding the conveyance of Conserved Habitat to appropriate public and private entities;

b. Option for the public acquisition of additional lands as Conserved Habitat and Public Recreation Areas provided that funds are appropriated and available within a specified period of time;

c. Provision for and assurances regarding the development and use of development areas;

e. Remedies in the event of defaults under the Agreement; and

f. Amendment and termination of the Agreement and this Habitat Conservation Plan.

3.
North Key Largo Public Land Acquisition and Management Committee

a.
In General

The North Key Largo Public Land Acquisition and Management Committee shall have been established in the Department of Natural Resources for the purposes of coordinating, supervising, managing, operating and maintaining land and water areas within the North Key Largo Management Area for wildlife habitat and public recreation purposes in accordance with this Habitat Conservation Plan.

b.
Powers

For the purposes set forth above, the Committee shall review and comment on proposed development within the North Key Largo Management Area; and shall be empowered to improve, repair, maintain and operate lands owned by the State of Florida, U.S. Fish and Wildlife Service, private persons or others; to enter into agreements with private and public landowners; to accept, hold and expend funds appropriated by the State or provided by

other governmental agencies or private interests; and to institute administrative and legal proceedings to enforce the provisions of the Habitat Conservation Plan. The powers conferred upon the Committee are in addition to the authority of existing agencies and shall not reduce or limit such existing authority in any way.

c.
Members

The Committee shall consist of seven members appointed as follows:

a. The Secretary of the Department of Natural Resources or his designated representative;

b. The Executive Director of the Florida Game and Freshwater Fish Commission or his designated representative;

c. The Secretary of the Department of Interior or his designated representative;

d. The Chairman of the Board of County Commissioners (Mayor) or his designated representative; and

e. Three persons appointed by the Governor as follows:

   i. a representative of statewide conservation interests;

   ii. a resident of Monroe County; and

   iii. a landowner in the North Key Largo Management Area.

d.
Mitigation Projects

The Management Board shall be responsible for overseeing all mitigation which are required by this plan except for mitigation which is necessary to meet the minimum standards of the Plan. Consideration of projects by the Board should be based on the following priorities:

First Order Activities (Recovery)

- Monitoring of endangered species on North Key Largo
- Enforcement of existing regulations which affect the survival of endangered species
- Culverting and elevation of Card Sound Road
- Ensure the elimination of aerial spraying of pesticides
- Provide for restoration of Dispatch Creek Slough

Second Order Activities (Enhancement)

- Control exotic plants within the Management Area
- Control trash accumulation within the Management Area
- Eliminate feral animals
- Restore abandoned roadbeds

Other Activities

- Implement other strategies for the recovery of endangered species
- Ensure the implementation of other strategies outlined in this HCP.

4.
Conserved Habitat

a.
Lands Comprising the Conserved Habitat

The Conserved Habitat consists of the land and water areas shown on Figure 8.

b.
Management and Operation of Conserved Habitat

The Conserved Habitat shall be managed and operated for wildlife conservation purposes in accordance with the provisions of this Habitat Conservation Plan.

5.
Public Recreation Areas

Public Recreation Areas shall be designated and managed for public recreation purposes consistent with the conservation purposes of this HCP including overnight accommodations, camping and parking facilities; boating; diving; restaurants; nature studies; education; other recreation uses; and accessory uses. No public recreation area shall be designated in the Conserved Habitat.

a.

Leases; Franchises; Management Agreements and Conveyances

In managing the Public Recreation Areas, the State of Florida may enter into leases, franchises, management and other agreements upon finding that it will promote the purposes of this Habitat Conservation Plan.

b.

Protection of Marine Resources

In managing the Public Recreation Areas, the State of Florida, in cooperation with federal agencies, should regulate marine use and anchoring in the adjacent waters to conserve and protect marine and coastal resources such as the coral reef habitat of the John Pennekamp State Park and the adjacent National Marine Sanctuary.

6.

Development Areas

a.

In General; Permitted Uses

The Development Areas identified in the following maps (Figures 13 through 17) may be developed and used only in accordance with the provisions and restrictions set forth in this Plan.

b.

Densities and Intensities

Allocated densities and maximum net densities allowable within the Development Areas are set out below.

	ALLOCATED DENSITY	MAXIMUM NET DENSITY
RESIDENTIAL		
Hammock	2.0 du/acre	10.0 du/acre
Transitional	.6 du/acre	10.0 du/acre
Scarified	1.2 du/acre	10.0 du/acre
HOTEL		
Hammock	4.0 Rooms/acre	15.0 Rooms/acre
Transitional	1.2 Rooms/acre	15.0 Rooms/acre
Scarified	2.4 Rooms/acre	15.0 Rooms/acre

Residential units may be exchanged for hotel rooms at a ratio of 1

residential unit for 2 hotel rooms.

c.
Timing

Except as specifically set out in this section, no construction activity shall be allowed within any Development Area prior to August 1, 1988. The owners of land within Development Areas may conduct field surveys and apply for and receive development permits prior to August 1, 1988, provided however, that no construction activity shall be actually commenced prior to August 1, 1988.

Development including construction may be undertaken in the following areas prior to August 1, 1988 subject to the listed conditions:

1) Ocean Reef Shores, Gulfstream Shores and Knowlson Colony Subdivisions - none;

2) JHT, Post-Nichols and Madeira Village Subdivisions - no construction on land located within 300 feet of the right-of-way of SR 905 shall be permitted until after August 1, 1988.

3) Ocean Reef Club - so long as development is consistent with the master plan approved by Monroe County;

4) Angler's Club - so long as permits issued by Monroe County are valid under the Monroe County Comprehensive Plan and Land Development Regulations; and

5) Port Bougainville and Garden Cove - so long as the development of regional impact development orders remain current and valid under Ch. 380 provided however, that development authorized as a substantial deviation shall be deferred until after August 1, 1988.

Notwithstanding any other provision of this Plan, any lands which were listed for acquisition pursuant to Section 253.023, Fla. Stat. (1985) may be developed prior to August 1, 1988 only if the development is consistent with the purposes in Section 253.023(3), Fla. Stat.

d.
Options

Landowners who desire to take advantage of the Section 10(a) permit shall grant as part of the Habitat Conservation Plan Agreement to the State of Florida an option to acquire their lands for a period of time provided, however, that at any time after

August 1, 1988 a landowner may terminate the option thirty (30) days after giving the Management Board sixty (60) days written notice.

e.

Planning and Approvals

No development shall be undertaken and no development order issued unless an application for development approval has been delivered to the Management Board and written comments provided in regard to compliance with this Plan are submitted by the Management Board to the permitting agency or the Management Board fails to submit a recommendation within 120 days after receipt of the application.

f.

Conditions of Development

i.

General Conditions

Required conditions for the development of any node are set out below. These conditions shall be met by any plan for development of each and every node.

Clearing More Than 20% of High Quality Hardwood Hammock:

If proposed development within any given node clears hardwood hammock in excess of the Open Space Ratio set out in Section 9-809 of the Monroe County Land Development Regulations, mitigation for such additional clearing shall be provided according to the following formulae:

1) Preservation in perpetuity through transfer to public ownership of 200 acres of mangrove wetland in the Conserved Habitat for each additional acre cleared; or

2) Preservation in perpetuity through transfer to public ownership of 4 acres of hardwood hammock in the Conserved Habitat for each additional acre cleared and the extinguishment of the development rights for 8 dwelling units appurtenant to the land; or

3) Preservation in perpetuity and replanting of hardwood hammock on 3 acres of successional habitat (returning to hardwood hammock) for each additional acre cleared. Specific target areas might include the Nike missile site and its line of sight field along with the burned areas on the Gong property; or

4) Preservation in perpetuity, replanting of hardwood hammock, and provision of at least 3 and no more than 6 rubble piles of 4 cubic yards of either rock or logs

on 2 acres of scarified land for each additional acre cleared. Specific target areas would include old abandoned road corridors, the Carysfort site and the Key Largo Beach and Tennis site.

Trapping Before Clearing:

"Extinction" trapping of woodrats and cotton mice for no less than 5 consecutive nights prior to the clearing of any hardwood hammock. Relocation of these animals shall be in accordance with policies to be determined by the U.S. Fish and Wildlife Service and the Florida Game and Fresh Water Fish Commission.

Host Plant Replacement:

Any torchwood or wild lime plants removed during clearing for development shall be replaced on a one-for-one basis as landscaping within the new development.

Marina Requirements:

Any development with a proposed marina shall provide one educational sign board explaining the sensitivity of coral reefs in the area. Before any marina permits are issued, anchor buoys designed to protect adjacent coral reefs shall be in place, and explanation of their use shall be provided on the educational sign board.

Performance Bond:

A performance bond equivalent to 125% of the estimated cost of any mitigation activity shall be posted with Monroe County prior to engaging in any mitigation activity.

ii.
Site Specific Conditions

Required conditions for the development of specific nodes are set out below. These conditions must be met by any plan for development of the specified node, and the cost of complying with these conditions shall be borne by the developer.

Gong Properties:

Development shall be focused on the northernmost portion of the Gong properites adjacent to the existing development of the Anglers Club/Ocean Reef Club.

(1) Predators of woodrats and cotton mice, such as raccoons and opposums, will be trapped and removed from the uplands in the Gong properties which will not be developed.

(2) An animal barrier will be erected along the border between the development area and the adjacent hammock preservation areas prior to the commencement of the woodrat and cotton mouse relocation from the development areas and predator removal from the preservation areas.

(3) All mangrove acreage, totalling 321 acres, shall be preserved.

(4) That portion of the Gong properties lying within the boundaries of the Crocodile Lake National Wildlife Refuge will be conveyed to the United States Fish and Wildlife Service.

(5) That portion of Old SR 905 located on the Northern Node/Gong properties which interferes with the historical flow of Dispatch Creek shall be removed.

(6) Culverts will be installed under SR 905 north of the intersection with Card Sound Road to facilitate improved tidal flushing of Dispatch Creek. A crocodile passageway will be constructed under 905 in connection with the installation of culverts.

(7) If a marina is authorized, the U.S. Fish and Wildlife Service will be provided a wet boat slip in the marina to facilitate manatee and crocodile patrols of North Key Largo and to initiate an awareness program for the public on the manatee and American crocodile. Limerock fill excavated from the marina site will be made available for the construction of woodrat and cotton mouse habitation piles on other sites in North Key Largo.

Gardner Properties:

Development of the Gardner properties shall be conditioned on:

1) removal and re-vegetation of the roadbed by the landowner and developer of all portions of SR 905 and the Card Sound Road extension that abut or cross the two parcels;

2) access to the developed property is limited to access through and from the Ocean Reef Club; and

3) the donation of 1200 acres of wetlands located west of SR 905 owned by the Gardner interests to an entity which will conserve and protect the natural habitat.

Carysfort:

A buffer of at least 300 feet in width shall be established and maintained along the entire SR 905 right-of-way frontage of the

property. The buffer shall be planted with native hammock vegetation with the intention of re-establishing a hammock corridor connecting the adjacent hammocks.

The marina channel and basin shall be back-filled to a depth of six feet to enhance the quality of the water.

Madeira Village:

A buffer of at least 300 feet in width shall be established and maintained along the entire 905 right-of-way frontage of the property. The buffer shall be planted with native hammock vegetation with the intention of re-establishing a hammock corridor connecting adjacent hammocks.

Ocean Forest:

A hammock buffer of an average of 300 feet in width with a minimum dimension of 200 feet shall remain undisturbed along the entire 905 right-of-way frontage of the property, except as necessary to provide entrance to the development.

Only a single entrance to the development shall be allowed.

Sea-To-Sound:

A hammock buffer of at least 300 feet in width shall remain undisturbed along the entire SR 905 right-of-way frontage of the property.

Access to the property shall use the same entrance from SR 905 as the Ocean Forest development.

Post Nichols:

- provide for the conservation of 1.73 acres of hammock along SR 905 in perpetuity
- provide $12,000 to the Nature Conservancy for purchase of other environmentally sensitive Keys land
- fund a 2 acre hammock revegetation project on the old missile base site
- provide $3,000 to fund a study of mortality of rodents during the development process.

Subdivisions:

Development of single family detached dwelling in Madeira Village, Knowlson Colony, Gulfstream Shores and Ocean Reef Shores shall include landscaping with torchwood and wild lime at the density of plant material required for a Bufferyard B under the Monroe County Land Development Regulations.

Port Bougainville:

If the Development Order currently controlling development of the Port Bougainville/Garden Cove DRI should become null and void, any further development of the site would be required to comply with the general conditions set forth in this Plan. In addition, the following specific conditions would apply:

1. Educational signage shall be posted at any marina warning of the sensitivity of crocodiles and coral reefs to human pressures.

2. All marina channels and basins shall be back-filled to a depth of six feet to enhance water quality.

3. A buffer of at least 300 feet in width shall be established and maintained along the entire SR 905 right-of-way frontage of the property. The buffer shall be planted with native hammock vegetation with the intention of re-establishing a hammock corridor connecting the adjacent hammocks.

KEY FOR NODE MAPS

KEY



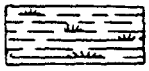
Node Boundary



Hardwood Hammock



Transitional Habitat (Salt Marsh and Buttonwood)

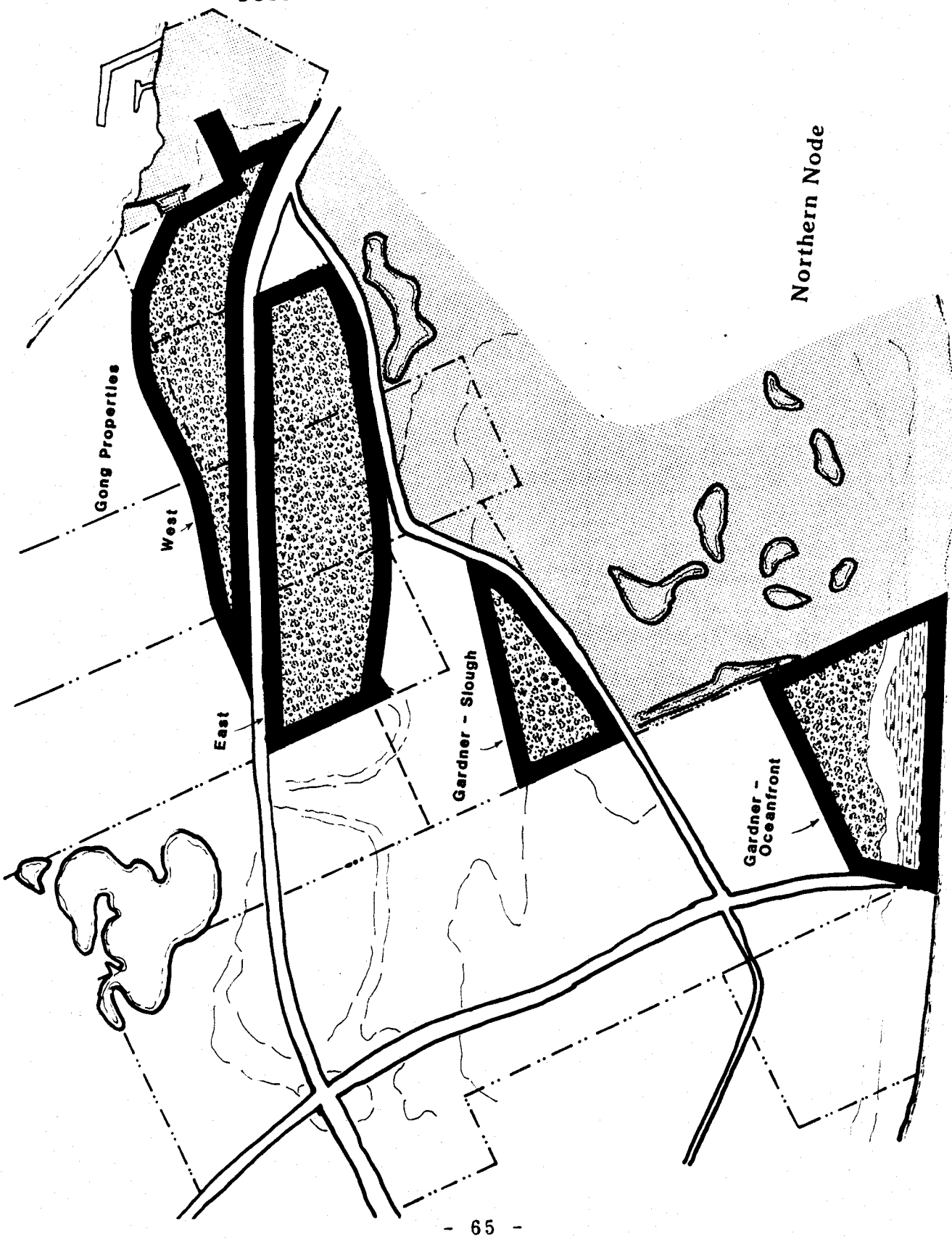


Mangrove



Disturbed or Scarified Land

FIGURE 13: NORTHERN NODE PROPERTIES



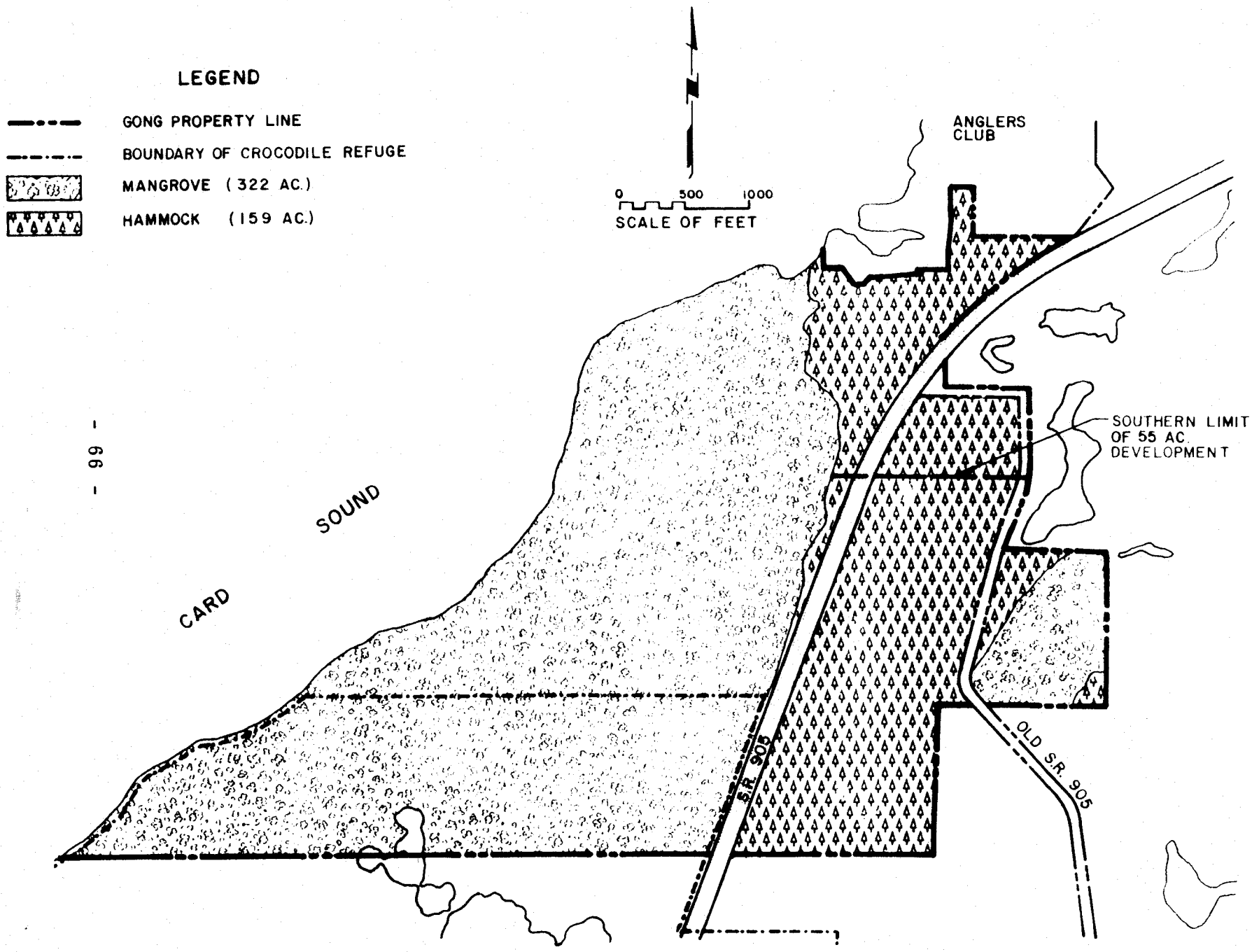
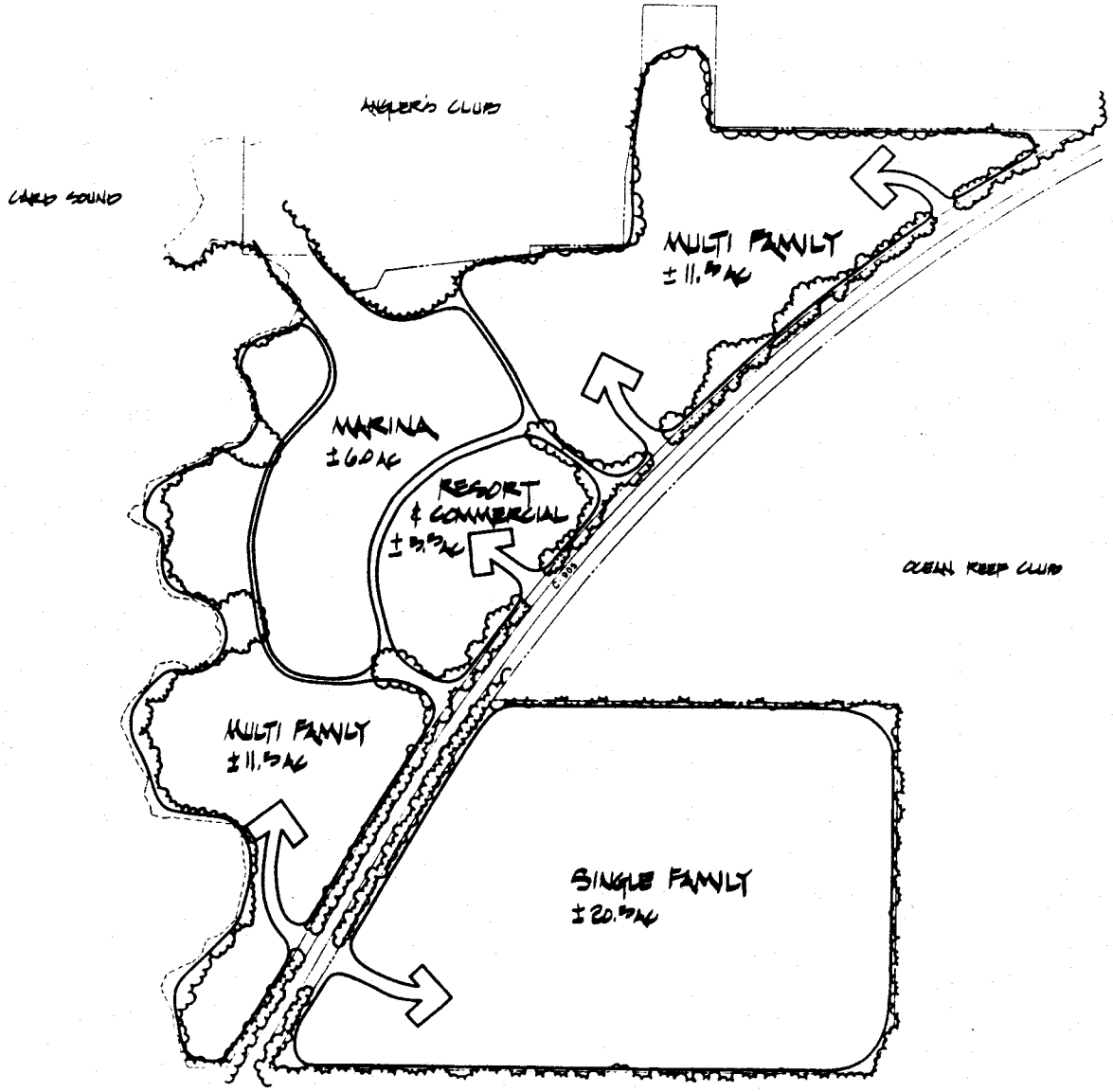


FIGURE 14: GONG PROPERTIES

FIGURE 15: GONG PROPERTIES - SCHEMATIC PLAN



Note - This plan prepared for illustrative purposes only.

Concept Plan for:
bayside

prepared for:
Edmond J. Gong

prepared by:
The Glyman Design Group
Planning and
Landscape Architecture

FIGURE 16:GONG PROPERTIES - CONCEPT PLAN



This plan assumes all buildings are 44' in height as per June 12, 1986 draft of H.C.P.

Represents 4 units per building complex.

Note - This plan prepared for illustrative purposes only.

Concept Plan for:

bayside

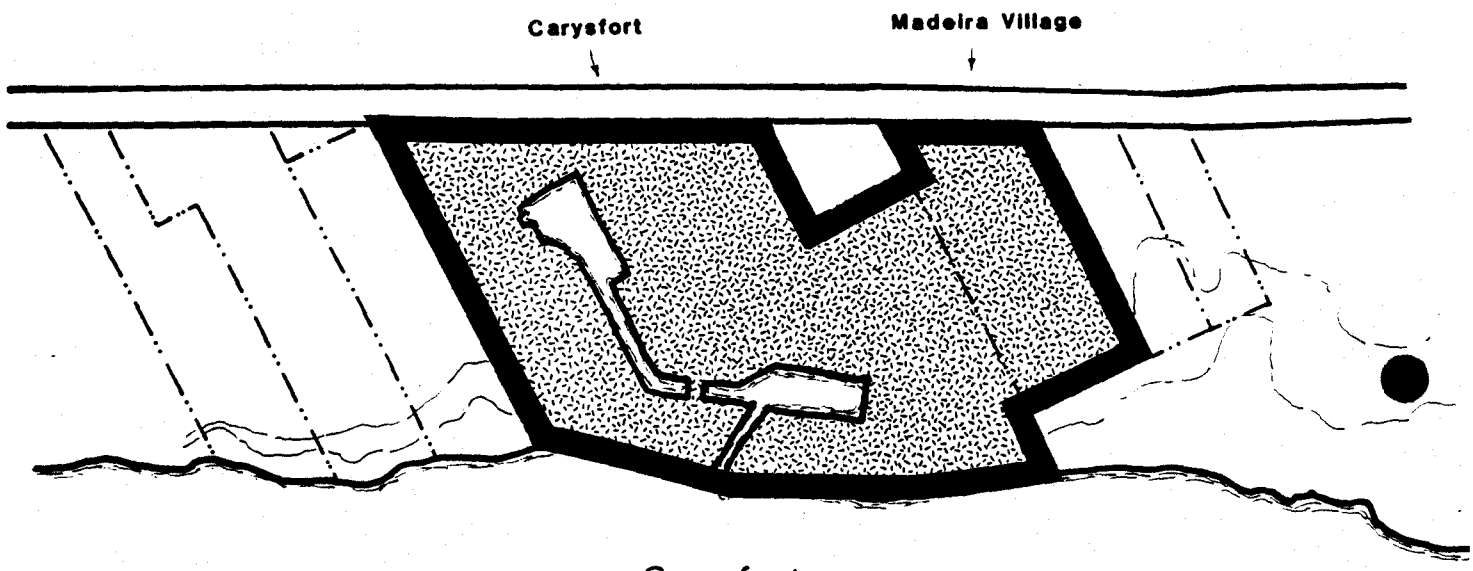
prepared for:
Edmond J. Gong

prepared by:
The Glyman Design Group
Planning and
Landscape Architecture

0 50 100 200 400

North

FIGURE 17: CARYSFORT/MADEIRA VILLAGE



Carysfort

FIGURE 18: OCEAN FOREST/SEA-TO-SOUND

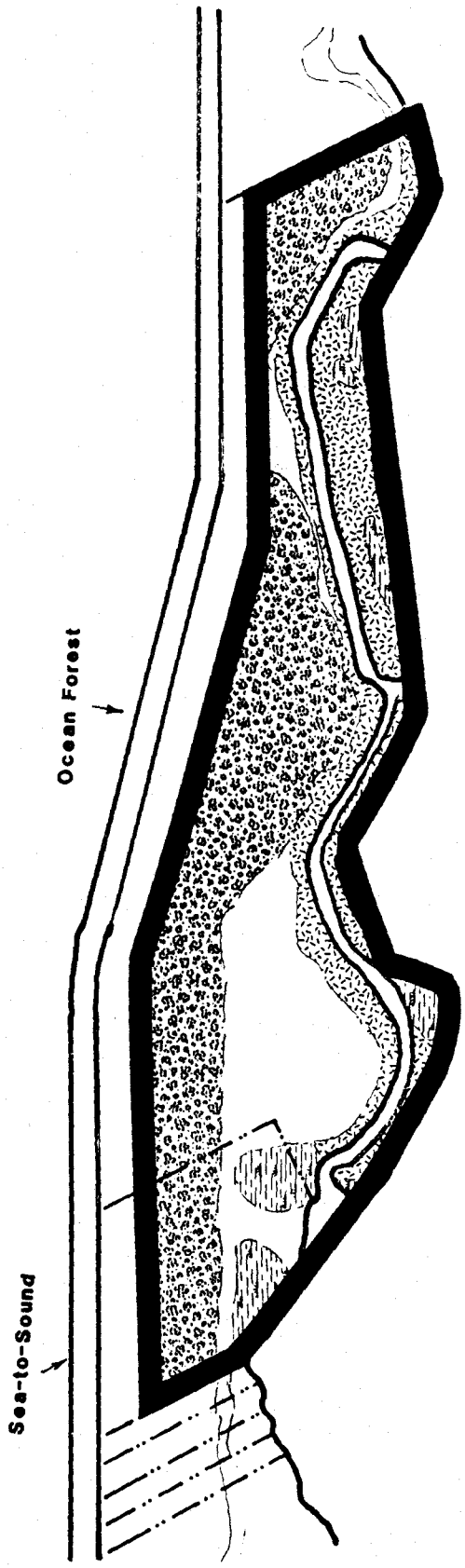
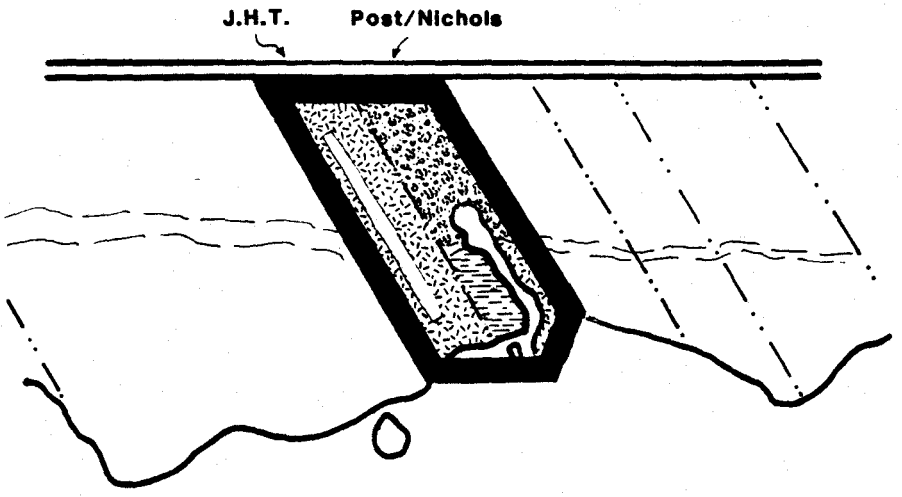
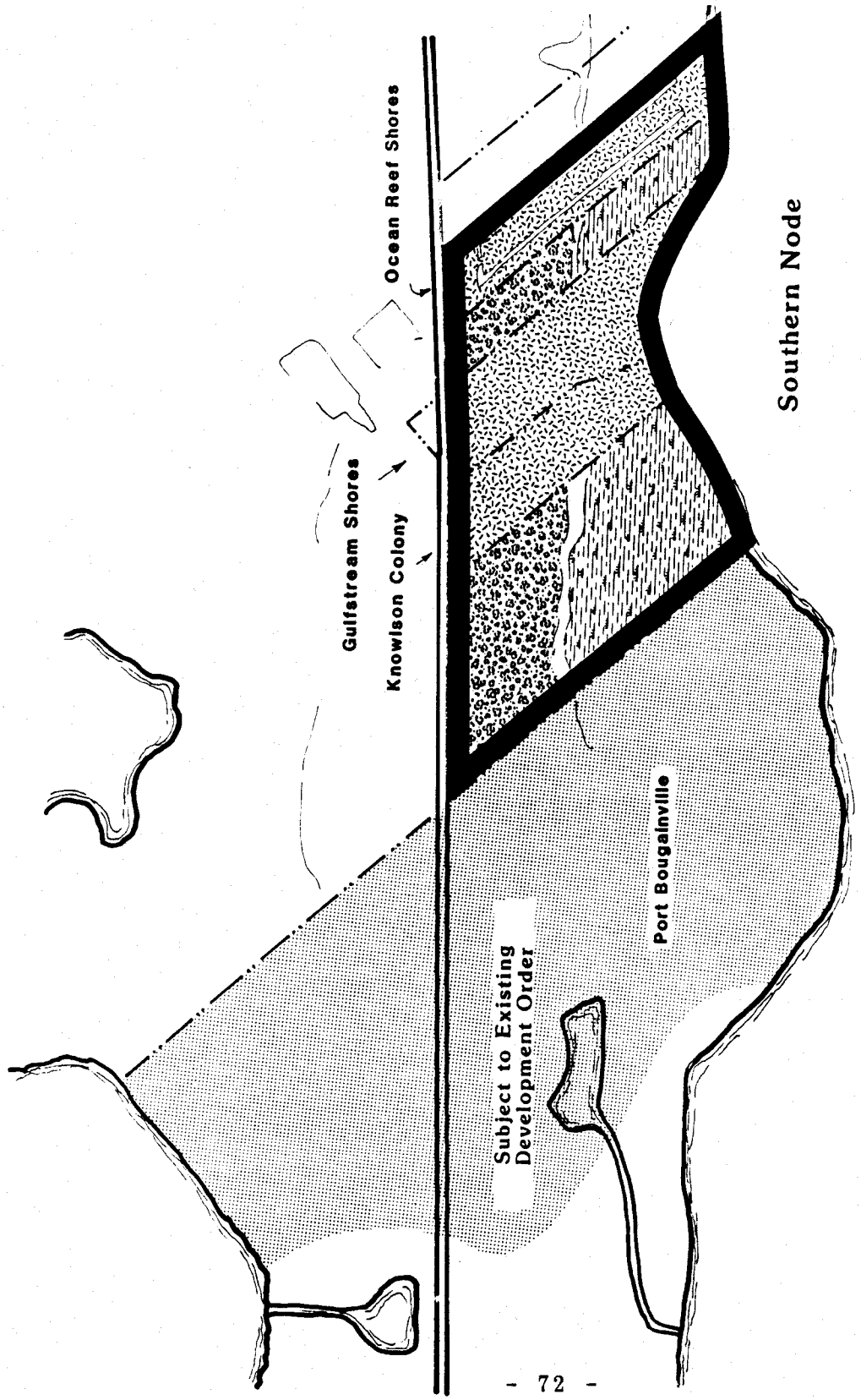


FIGURE 19: JHT/ POST NICHOLS



JHT/Post Nichols

FIGURE 20: SOUTHERN NODE/SOUTHERN SUBDIVISIONS



iii.
Applicable Provisions From The Monroe County Land Development Regulations

Except as expressly set out in this Plan, all development shall be subject to each and every requirement of the Monroe County Comprehensive Plan and Land Development Regulations.

Shoreline Setback

Where necessary to preserve hammock areas in compact units, the shoreline setback for all shoreline types may be reduced to twenty (20) feet provided that the mitigation strategies employed by the developer demonstrate that no net loss of endangered species will result from the proposed development.

Open Space Ratio

Where the developer proposes to implement mitigation strategies which result in no set loss of any endangered species the open space ratio may be reduced subject to the specific mitigation ratios set out in this Plan.

Clustering

The clustering provisions may be waived where a developer can demonstrate that the net loss of endangered species can be reduced by clustering which is inconsistent with the Monroe County Land Development Regulations.

7.
Financing and Services

a.
In General

A major element of this Habitat Conservation Plan is to provide for the financing of its implementation, including the development, operation, maintenance and replacement of improvements for wildlife conservation. Funds for mitigation and habitat maintenance shall be made available to all lands on North Key Largo. Efforts to implement the USFWS Recovery Plans for the affected endangered species shall be given first priority.

b.
Assessments

As a condition precedent to the approval of any development, a participating Landowner shall covenant to pay an open space assessment fee of $2.00 per overnight accommodations unit per night or $2.00 per week per residential dwelling unit (to be adjusted

annually for inflation) to the Management Committee for the maintenance and operation of the Conserved Habitat. Said covenant shall be in the form attached hereto as Exhibit __ with the intent that it shall run with the land and burden the respective unit and shall be recorded in the official records of Monroe County.

c.

Municipal Services Taxing Unit

Monroe County shall establish a Municipal Services District to assist in the financing of the implementation of this plan. The MSD should be limited to an ad valorem tax levy of not greater than .5 mils. Ths MSTU should levy special assessments on all properties that are specially benefitted by the implementation of the HCP.

d.

Credit Permitted

Consideration should be given in all financing mechanisms to provide a credit for any payments by participating landowners in assisting in the development of this HCP as verified by the Management Committee.

e.

USFWS Crocodile Refuge

The USFWS is encouraged and should apply the funds presently appropriated for the acquisition of lands in the Crocodile Refuge to that purpose.

f.

SR 905 Toll

The County should establish a toll for the purpose of completing the road improvements described in the HCP including the elevation of Card Sound Road in an amount of not less than $_____ per vehicle per crossing (or $_____ per year per driver), with provision for vehicles traversing Card Sound Road between Card Sound Bridge and the intersection of US 1 and SR 905.

g.

Development Fees

All development shall pay a development fee of $2500 per dwelling unit or equivalent at the time of the issuance of a building permit. Such funds shall be used exclusively for the construction of capital facilities needed for implementation of this Plan.

All funds collected for the implementation of this Plan shall be administered through intergovernmental agreements between the collecting agencies and the Management Board. Funds shall be

expended according to the priority established by the Plan except for annual expenses such as personal salaries. Each year the Management Board shall establish a budget for the upcoming fiscal year, specifying operational and maintenance costs. In the event the development fees and the annual assessment together with all other sources of funds are insufficient to meet the budgeted needs, the MSD shall levy, within its millage cap an ad valorem tax sufficient to meet the Management Board's budget.

8.
Amendments; Reservation of Authority

a.
Amendments

This Habitat Conservation Plan may be amended in accordance with the following conditions:

a. No more than one amendment shall be permitted in any calendar year.

b. Any application to the County for such an amendment shall be accompanied by a report by a biologist approved by the North Key Largo Management Board describing the anticipated impact on the endangered species generally and whether the amendment will jeopardize the continued existence of such species.

c. Notice of any such proposed amendment together with the above-mentioned report shall be provided by the County to USFWS, the Management Board, DCA, DNR, FGFFC, any affected landowner and those individuals and groups previously requesting such notice in writing together with a copy of the above-mentioned report at least thirty (30) days prior to approving or disapproving of such amendment.

d. Reasonable opportunity for written and oral comment regarding the proposed amendment shall be provided to the public and those required to receive notice, as provided above, prior to approving or disapproving of such amendment.

e. As a condition precedent to approving any amendment, the Board of County Commissioners shall make specific written findings that:

i. The amendment will not jeopardize the continued existence of any of the endangered species; and

ii. Any significant adverse impact on the endangered species or the development value of Development Areas anticipated from the amendment will be mitigated to the greatest extent practicable.

f. Any amendment must be submitted to USFWS for consultation under Section 7 of the Endangered Species Act to ensure that the amendment does not jeopardize the continued existence of the endangered species.

b.

Reservation of Authority

Notwithstanding any of the foregoing to the contrary but subject to the provisions of this Section H, the County reserves all authority to take property by eminent domain and to take whatever action is necessary or desirable to provide for the health, safety and welfare of the public; provided that, to the extent permitted by law, it shall take all practicable actions to mitigate any significant adverse impact on the endangered species and the value of the Development Areas for development uses.

VII.

DEFINITIONS

The following words are used throughout the Plan and their specific meaning is set out below to prevent any misinterpretation.

A-1. **ACCESSORY USE** or **ACCESSORY STRUCTURE** means a use or structure that is subordinate to and serves a principal use or structure; is subordinate in area, extent and purpose to the principal use or structure served; contributes to the comfort, convenience or necessity of occupants of the principal use or structure served; and is located on the same lot or lots under the same ownership and in the same land use district as the principal use or structure. Accessory uses include the utilization of yards for home gardens provided that the produce of the garden is for non-commercial purposes; pro-

vided however, that in no event shall an accessory use be construed to authorize a use not otherwise permitted in the district in which the principal use is located and in no event shall an accessory use be established prior to the principal use to which it is accessory.

A-2 **ACQUISITION PROGRAM** means any program of the State of Florida or any other agency, public or private, for the acquisition of lands for conservation or recreational purposes, whether established by special or general law, including but not limited to Conservation and Recreational Lands (C.A.R.L.) and Save Our Coast (S.O.C.).

B-1. **BOARD** means the Board of County Commissioners of Monroe County.

B-2. **BUILDING** means a structure which is located on land or water and which can be used for housing, business, commercial, agricultural, storage or office purposes, either temporarily or permanently.

B-3. **BUILDING CODE** means the Standard Building Code as applied to the Florida Keys as defined in Section 161.52 et seq., the Coastal Zone Protection Act of 1985.

C-1. **CAMPGROUND SPACE** means a space, whether improved or unimproved, used for tent camping including pop-ups by a single housekeeping unit for tenancies of less than six months.

C-2. **CANOPY TREES** means tall trees that form the uppermost leaves in a hardwood hammock area.

C-3. **CAPACITY** means the capability of a facility to serve the needs of a user such as the number of vehicles a road can safely and efficiently carry.

C-4. **CAPITAL IMPROVEMENTS** means the planning of, engineering for, acquisition of land or equipment, and the construction of improvements and facilities but does not include routine maintenance.

C-5. **CONDITIONS OF DEVELOPMENT** means with respect to the Development Areas and the Conserved Habitat, those conditions and requirements of development provided in Section ____ and set forth with respect to each area in Attachment ___.

C-6. **CONSERVED HABITAT** means those land and water areas shown on the map attached hereto as Figure 1 as "Conserved Habitat" together with additional lands and water areas designated as such pursuant to the Conserved Habitat and Public Recreation Areas Operating Agreement.

C-7. **CONSERVED HABITAT AND PUBLIC RECREATION AREA OPERATING AGREEMENT** means the agreement entered into among the various public agencies holding and operating lands within the North Key Largo Area.

C-8. **COTTON MOUSE** means the Key Largo cotton mouse (Peromyscus gossypinus allapaticola).

C-9. **COUNTY** means the County of Monroe in the State of Florida.

C-10. **CROCODILE** means the American crocodile (Crocodylus acutus).

C-11. **CROCODILE REFUGE** means the Crocodile Lake National Wildlife Refuge which is located on the westerly portions of North Key Largo and has been established by the USFWS as a national wildlife refuge and is shown on Figure 1 attached hereto, some of which is owned by USFWS and some by private landowners.

D-1 **DCA** means the State Department of Community Affairs.

D-2. **DEVELOPER** means any person, including a governmental agency, undertaking any development as defined in this Plan.

D-3. **DEVELOPMENT** means the carrying out of any building activity, the making of any material change in the use or appearance of any structure or land or water, or the subdividing of land into two or more parcels.

(a) Except as provided in subsection (c) hereof, for the purposes of these regulations, the following activities or uses shall be taken to involve "development:"

(1) A reconstruction, alteration of the size, or material change in the external appearance of a structure on land or water.

(2) A change in the intensity of use of land, such as an increase in the number of dwelling units in a structure or on land or a material increase in the number of

businesses, manufacturing establishments, offices, or dwelling units in a structure or on land.

(3) Alteration of a shore or bank of a seacoast, lake, pond, or canal, including any work or activity which is likely to have a material physical effect on existing coastal conditions or natural shore and inlet processes.

(4) Commencement of drilling (except to obtain soil samples), mining, or excavation on a parcel of land.

(5) Demolition of a structure.

(6) Clearing of land, including clearing or removal of vegetation and including any significant disturbance of vegetation or substrate (soil) manipulation.

(7) Deposit of refuse, solid or liquid waste, or fill on a parcel of land.

(b) DEVELOPMENT includes all other activity customarily associated with it. When appropriate to the context, "development" refers to the act of developing or to the result of development. Reference to any specific operation is not intended to mean that the operation or activity, when part of other operations or activities, is not development. Reference to particular operations is not intended to limit the generality of this definition.

(c) For the purpose of these regulations the following operations or uses shall not be taken to involve "development:"

(1) Work involving the maintenance, renewal, improvement, or alteration of any structure, if the work affects only the color or decoration of the exterior of the structure or interior alterations that do not change the use for which the structure was constructed.

(2) Work involving the maintenance of existing landscaped areas and existing rights-of-way such as yards and other non-natural planting areas.

(3) A change in use of land or structure from a use within a specified category of use to another use in the same category unless the change involves a change from a use permitted as of right to one permitted as a minor or major conditional use or from a minor to a major conditional use.

(4) A change in the ownership or form of ownership of any parcel or structure.

(5) The creation or termination of rights of access, riparian rights, easements, covenants concerning development of land, or other rights in land unless otherwise specifically required by law.

(6) The clearing of survey cuts or other paths of less than four (4) feet in width and the mowing of vacant lots in improved subdivisions and areas that have been continuously maintained in a mowed state prior to the effective date of this Plan, the trimming of trees and shrubs and gardening in areas of developed parcels that are not required open space and the maintenance of public rights of way and private accessways existing on the effective date of these Land Development Regulations or approved private rights of way.

D-4. **DEVELOPMENT AREAS** means those areas designated as potential development areas on Figure ____ of this Habitat Conservation Plan.

D-5. **DEVELOPMENT RIGHT** means the right to use real property for uses or purposes permitted by the Comprehensive Plan.

D-6. **DISTURBED LAND** means land that manifests signs of environmental disturbance which has had an observable effect on the structure and function of the natural community which existed on the site prior to the disturbance.

D-7. **DNR** means the State Department of Natural Resources.

D-8. **DWELLING UNIT** means a self-sufficient room or combination of rooms which are designed for or used as a residence by a single housekeeping unit. The abbreviation DU shall mean dwelling unit.

E-1. **ENDANGERED AND THREATENED SPECIES** means plant or animal species listed as such under the provisions of the Endangered Species Act, 16 U.S.C. §§1531 et seq. and/or §581.45 Fla. Stat. and the Florida Endangered and Threatened Species Act, §372.072.

E-2. **ENDANGERED SPECIES ACT** means the federal Endangered Species Act of 1973, as amended (16 U.S.C. §§1531-1543).

E-3. **ENHANCEMENT** means measures which improve fish and wildlife resources beyond that which exist without the project and which cannot be used to satisfy the appropriate mitigation planning goal.

F-1. **FRESHWATER WETLANDS** means wetland areas with either standing water or saturated soil, or both, where the water is fresh or brackish. The vegetation common in freshwater wetlands in the Keys include the following species:

Cladium jamaicensis	Saw grass
Conocarpus erectus	Buttonwood
Eleocharis celluosa	Spike rush
Laguncularia racemosa	White mangrove
Rhizophora mangle	Red mangrove
Typha spp.	Cattail

G-1. **GOVERNMENTAL AGENCY** means:

(a) The United States or any department, commission, agency, or other instrumentality thereof;

(b) The State of Florida or any department, commission, agency, or other instrumentality thereof;

(c) Any local government or any department, commission, agency, or other instrumentality thereof; or

(d) Any school board or other special district, authority, or governmental entity.

H-1. **HABITAT CONSERVATION PLAN** or **HCP** means this plan.

H-2. **HABITAT CONSERVATION PLAN AGREEMENT** means the agreement to be entered into among concerned public agencies and private landowners pursuant to Section _____.

H-3. **HIGH HAMMOCK** is an upland, hardwood forest community in which the following species of plants represent a component of the flora:

Ateramnus lucidus	Crabwood
Bursera simaruba	Gumbo limbo
Calyptranthes pallens	Pale lidflower
Columbrina elliptica	Soldierwood
Drypetes lateriflora	Guiana plum
Eugenia confusa	Redberry stopper
Eugenia rhombea	Red stopper
Exostema caribaeum	Princewood
Exothea paniculata	Inkwood
Ficus aurea	Strangler fig
Ficus citrifolia	Short-leaf fig
Guettarda elliptica	Everglades velvetseed
Guettarda scabra	Rough velvetseed
Hamelia patens	Scarletbush
Hypelate trifoliata	White ironwood
Krugiodendron ferrum	Black ironwood
Lasciacis divaricata	Wild bamboo
Lysiloma latisiliquum	Wild tamarind
Mastichodendron foetidissimum	Mastic
Nectandra coriacea	Lancewood
Psychotria ligustrifolia	Wild coffee
Psychotria nervosa	Wild coffee
Simarouba glauca	Paradise tree
Trema lamarckiana	West Indies trema
Trema micrantha	Florida trema

I-1. **INVASIVE EXOTIC SPECIES** means Melaleuca (Melaleuca quinquinerva), Australian Pine (spp. Casuarina), Brazilian Pepper (Schinus terebinthifolius), Leatherleaf (Colubrina asiatica), and Sapodilla (Manilkara zapota).

L-1. **LAND** means the earth, at or below the surface, that lies above mean high tide for lands subject to tidal inundation and mean high water for freshwater bodies of water.

L-2. **LOT** means a parcel of land occupied or intended for occupancy by an individual use including one main structure together with accessory structures, yards, open spaces, buffer areas and parking spaces.

M-1. **MANAGEMENT BOARD** means the North Key Largo Management Board set up by state legislation in the form specified in this HCP for the management and operation of conserved habitat in the North Key Largo Management Area.

M-2. **MANGROVE COMMUNITY** means a wetland plant association subject to tidal influence where the vegetation is dominated by one or more of the following three species of mangroves:

Avicennia germinans	Black mangrove
Laguncularia racemosa	White mangrove
Rhizophora mangle	Red mangrove

M-3. **MANMADE WATER BODY** means a water body that was created by excavation by mechanical means under human control and shall include a canal, cut basin or channel where its edges or margins have subsequently been modified by natural forces.

M-4. **MARINA** means a facility for the storage (wet and dry), launching and mooring of boats together with accessory retail and service uses including restaurants and live-aboards.

M-5. **MEAN SEA LEVEL** (MSL) means the average height of the sea for all stages of the tide. For the purposes of these regulations, the term is synonymous with National Geodetic Vertical Datum (NGVD).

M-6. **MITIGATION** means

a. Avoiding the impact altogether by not taking a certain action or parts of an action.

b. Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

c. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

d. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

e. Compensating for the impact by replacing or providing substitute resources or environments.

M-7. **MONROE COUNTY COMPREHENSIVE PLAN** means the Monroe County Comprehensive Plan adopted and amended pursuant to section 163.3161 et seq., Florida Statutes.

N-1. **NORTH KEY LARGO ACT** means the State legislation to establish the North Key Largo Management Board.

N-2. **NORTH KEY LARGO MANAGEMENT AREA** or **MANAGEMENT AREA** means the land and water area designated as such on the map attached hereto as Figure 1.

O-1. **OPEN SPACE** means any portion of a parcel or area of land or water which is open and unobstructed from the ground to the sky including areas maintained in a natural and undisturbed character. Open space shall not include water below the mean high water line, or areas covered with buildings, sidewalks, patios, parking areas, drives or other paved areas, but the area of land under docks, piers and elevated walkways and 50% of areas paved with permeable materials shall be considered open space.

O-2. **OPEN SPACE RATIO** means the percentage of the total gross area of a parcel that is open space. (O.S.R.)

O-3. **OWNER** means any part owner, joint owner, tenant in common, tenant in partnership, joint tenant or tenant by the entirety with legal or beneficial title to the whole or to part of a building or land.

P-1. **PARCEL OF LAND** means any quantity of land and water capable of being described with such definiteness that its location and boundaries may be established, which is designated by its owner or developer as land to be used or developed as a unit, or which has been used or developed as a unit.

P-2. **PARKS** means publically owned lands used for active or passive recreational purposes or as a refuge for wildlife.

P-3 **PARTICIPATING AGENCY** means any agency which has agreed to sign the North Key Largo Plan Agreement. The agencies currently expected to be parties to the agreement include Monroe County, DCA, FG&FFC, DER, DNR, and USFWS.

P-4. **PERMANENT RESIDENTIAL UNIT** means a dwelling unit that is designed for, and capable of, serving as a residence for a full housekeeping unit which includes a kitchen composed of at least a refrigerator and stove.

P-5. **PERSON** means an individual, corporation, governmental agency, business trust, estate, trust, partnership, association, two or more persons having a joint or common interest, or any other legal entity.

P-6. **PHYSICAL DEVELOPMENT** means the placement or erection of any structure (including, but not limited to, any building, road, pipe, conduit, aquaduct, telephone line, and electrical power transmission and distribution line); the dredging or filling of any land or water area; the grading, removing, mining or extraction of any materials; the construction, re-construction, demolition, or alteration of the size of any structure; and the removal of major vegetation.

P-7. **PLAN** means the Monroe County Comprehensive Plan, which constitutes the required elements of the County's Comprehensive Plan adopted pursuant to Section 163.3177 Fla. Stat.

P-8. **PLATTED LOT** is a lot which is identified on a plat that was approved by the Board of County Commissioners and duly recorded.

P-9. **PUBLIC BUILDINGS AND USES** means office and service buildings, uses, or facilities owned or operated by a governmental agency which are compatible with or provide services to the immediate vicinity in which the building is located.

P-10. **PUBLIC RECREATION AREA(S)** means any lands designated as Development Areas which are acquired by the State for public recreation purposes.

R-1. **RECREATIONAL RENTAL USE** means a public or private area providing rental facilities for overnight or short-term occupancy, including campgrounds (commercial), camps (day or youth), and recreational vehicle parks.

R-2. **RESIDENCE** or **RESIDENTIAL USE**, as applied to any lot, plat, parcel, tract, area or building, means used or intended for use exclusively for dwelling purposes, but not including hotel rooms.

S-1. **SALT MARSH AND BUTTONWOOD ASSOCIATIONS** means two plant associations that are sometimes collectively or individually referred to as the "transitional zone." The salt marsh community is a wetland area subject to tidal influence wherein the vegetation is dominated by non-woody groundcovers and grasses. The vegetation may include but is not limited to the following non-woody species:

Sporobilus virginicus	Dropseed
Batis maritima	Saltwort
Distichlis spicata	Salt grass

Monanthochloe littoralis	Key grass
Salicornia spp.	Glasswort
Sesuvium portulacastrum	Sea purslane
Spartina spartinae	Cordgrass
Fimbristylis castanea	Chestnut sedge

Woody vegetation that may be present includes the three species of mangroves, as well as buttonwood (Conocarpus erectus); however, the salt marsh community is distinguished by the dominance of non-woody plants, and the woody species have a coverage of less than forty percent. The salt marsh community may be associated and intermixed with areas of almost bare ground on which the vegetation may be limited to mats of periphyton.

The buttonwood association is an association that is usually present in the more landward zone, and may intermix with more upland communities. The vegetation may include (but is not limited to) the following species:

Sporobilus virginicus	Dropseed
Borrichia spp.	Sea oxeye daisy
Bumelia celastrina	Saffron plum
Coccoloba uvifera	Sea grape
Conocarpus erectus	Buttonwood
Erithalis fruticosa	Black torch
Fimbristylis castanea	Chestnut sedge
Jacquinia keyensis	Joewood
Lycium carolinianum	Christmas berry
Maytenus phyllanthoides	Mayten
Spartina spartinae	Cordgrass

The buttonwood association is distinguished from the salt marsh association by the dominance of buttonwood trees, usually occurring as an open stand that permits the growth of an understory of groundcovers and shrubs. The buttonwood association is, in turn, distinguished from more upland communities by the presence of graminoids and halophytic groundcovers under its open canopy, and generally by the lack of an appreciable layer of humus and leaf litter.

S-2. **SCARIFIED LAND** means an area that has been cleared of some or all native vegetation and/or topographically modified by human action.

S-3. **SCHAUS SWALLOWTAIL** or **SCHAUS** means the Schaus swallowtail butterfly (Heraclides aristodemus ponceanus).

S-4. **SECTION 10(a) PERMIT** means a permit issued by the USFWS pursuant to the provisions of Section 10(a) of the

federal Endangered Species Act to incidentally take an endangered species in the course of carrying out an otherwise lawful activity.

S-5. **SETBACK** means an open space at grade between a building and the property line of the lot on which the building or structure is located, unoccupied and unobstructed from the ground upward, except for fences or as otherwise provided in these regulations. In measuring a set back, the horizontal distance between the lot line and the further most projection of the main building shall be used. Every required front setback from a street shall be measured at right angles (90°) from the property line.

S-6. **SPECIES OF CONCERN** means the species listed in Figure _____ hereto.

S-7. **SPECIMEN TREE** is any tree with a diameter at breast height that is seventy-five percent (75%) of the record tree of the same species for the State of Florida.

S-8. **STATE** means the State of Florida.

S-9. **STRUCTURE** means anything constructed, installed, or portable, the use of which requires a location on a parcel of land. It includes a movable building which can be used for housing, business, commercial, agricultural, or office purposes, either temporarily or permanently. "Structure" also includes roads, walkways, paths, fences, swimming pools, tennis courts, poles, pipelines, transmission lines, tracks, signs, cisterns, sewage treatment plants, sheds, docks, mooring areas, off-shore swimming platforms and other accessory construction.

S-10. **SUBMERGED LAND** means land below the mean high tide or mean high water line.

T-1 **"TAKE"** as defined in Section 1533 of the Endangered Species Act means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. Take also means any action which results in significant environmental modification or degradation, including those acts significantly affecting critical habitat of the species. See Palila v. Hawaii Department of Land and Natural Resources, 471 F. Supp. 985 (1979).

T-2. **TEMPORARY RESIDENTIAL UNIT** means a dwelling unit used for transient housing such as a hotel, motel or guestroom that does not contain a kitchen or a space for the parking of a mobile home or travel trailer park.

T-3. **THREATENED** and **ENDANGERED SPECIES** means plant or animal species listed as such under the provisions of the Endangered Species Act, 16 U.S.C. §§1531 et seq. and/or §581.185, Fla. Stat. and the Florida Endangered and Threatened Species Act, §372.072.

T-4. **TRANSITIONAL HABITAT** means the saltmarsh and buttonwood association.

U-1. **USFWS** means the United States Fish and Wildlife Service.

W-1. **WETLANDS** means that land which is subject to Section 403.91, Fla. Stat.

W-2. **WOODRAT** means the North Key Largo Woodrat (Neotoma floridana smalli).

APPENDIX A

Background and History of the Development of the North Key Largo Habitat Conservation Plan

A.
METHODOLOGY

1.
Historic Perspective

Historically, the planning of land and natural resources has been delegated in large part to the private sector as initiator and proponent of specific land uses, with the public interest being protected in the main by local agencies charged with the review and regulation of proposed uses.

During the late 1960's and 1970's, it became apparent that the traditional system was not working because "externalities," that is, the social and environmental impacts of piece-meal development proposals, were not being adequately addressed in the context of traditional development review. At all levels of government, far-reaching regulatory programs were enacted to address specific concerns such as growth management in areas of critical state concern, air and water quality, wetlands, and wildlife (including critical endangered species). These programs have generally resulted, however, in a fragmented regulatory system characterized by a number of different private and public sector interests, each with only limited power and authority to address increasingly complex environmental concerns.

A major theme of the National Environmental Policy Act (NEPA), 42 U.S.C. §4321 et seq., was the need to coordinate the actions of the various agencies and interests in the planning of projects which would have a significant impact on the environment. To this end, it established the requirement for the sharing and coordination of information regarding proposed projects. Experience under the Act suggested the importance of early consultation and coordination in project planning efforts -- before commitments and time pressures foreclose less environmentally damaging options. This early planning, consultation and cooperation among governmental agencies and the public has evolved into the concept of "scoping." [40 C.F.R. §1501.7. See generally, N. Yost, "The Governance of Environmental Affairs -- Toward Consensus" (Aspen Institute for Humanistic Studies 1982).]

The underlying approach in developing the HCP is the "scoping" process contemplated by NEPA -- the coordination or bringing together of all of the legitimate interests, public and private, concerned with the project at the earliest possible time to fairly and fully explore all potential impacts and reasonable alternatives to the project with a view of looking beyond the capabilities and authority of each participant to the development of a project plan which effects the legitimate goals of project proponents while maximizing protection of the environment.

2.
Elements of the Plan

Focal Point Plan

The HCP focuses on a limited group of issues related to the planning of North Key Largo, those related to the reconciliation of development and wildlife (particularly endangered species) concerns. Accordingly, it may be referred to as a "focal point plan." It is not a substitute for the County's Comprehensive Plan or general State or federal agency plans and is consistent with each of them. It will hopefully provide the basis for a common element for all such plans with respect to the issues covered by the conservation plan.

Regulatory Significance

The HCP will not have any regulatory significance until it is adopted by the various governmental agencies involved in the HCP process. It will simply be a recommended element which is to be included in the plans, regulations, permits or actions of the various governmental agencies involved provided that the plan satisfies the procedural and substantive requirements of each program. It is anticipated that the Plan, by virtue of the cooperative nature of the HCP process, will be given significant weight and will provide the basis for common and cooperative action. Once adopted by each agency and included in their plans and programs, it will then, of course, have such significance.

Regulatory and Programmatic

The HCP includes both regulatory and programmatic elements. For example, it not only contemplates regulations that might be adopted by the various agencies, but also sets forth management and operational programs that should be undertaken. In addition, it suggests private actions that are necessary to carry out the Plan.

Agreement and Assurances

The HCP contemplates a number of mutually dependent commitments and assurances among the public and private sector actors in carrying out the plan (for example, commitments with respect to the dedication of lands for habitat conservation). These are to be the subject of an agreement among the pertinent agencies and interests.

3.
The Process

The approach used to develop the HCP is similar to the NEPA "scoping process." It was the intent of the HCP process to maintain the continued involvement of the public and private sector interests that compose the Study Committee to review and comment upon the alternatives which are developed to reconcile the conflicts between development and wildlife habitat concerns. As part of the scoping process, the Study Committee also considered the significant effects of all such alternatives on the environment and developed means which can be used to mitigate or avoid such adverse effects.

In analyzing and assessing the significant effects of the range of alternatives, the Study Committee's actions were developed by "consensus"; that is, the consensus process assured that the description of alternatives developed and their impacts were complete and accurate and that all reasonable points of view regarding them were fairly and accurately represented. While it would be desirable to have the Committee as a whole concur that one alternative is "preferred," the HCP reflects a primary objective together with several alternatives among which pertinent agencies may have to choose. Similar to the environmental impact statement process from which the scoping process is derived, the HCP process will provide the decision-makers with a great deal of information which all interests have had the opportunity to develop or comment upon and the flexibility to develop a proposal which could serve to resolve the land use conflicts on North key Largo.

a.
Institutional Elements.

As mentioned above, one of the major purposes of the scoping process for developing the HCP was its focus on involving the participation of all interested and affected local, State and federal governmental agencies in the decision-making process. The advantage that this involvement provided was that ongoing governmental regulatory programs and their effect on any planning decisions, such as the County's Comprehensive Plan, were taken into consideration and decisions were made which are compatible and in accordance with those planning activities. In addition to the governmental agencies, the HCP "scoping" process encouraged the active participation of the private sector proponents as well as members of the general public who may be affected by the land use planning decisions.

b.
Prototype Alternatives Analysis: Research and Evaluation

In order to evaluate the various alternatives which were developed during the HCP process, there were a number of elements to be considered, including the ecology of North Key Largo, traffic, public safety and fiscal impacts.

As discussion and analysis proceeded, the range of alternatives was narrowed and revised by the Committee to a few alternatives and then, eventually to a single preferred alternative. This single preferred alternative is in fact a combination of several alternatives.

c.
Proposed HCP Components

Once the preferred alternative was selected, the Habitat Conservation Plan was drafted. The HCP identifies those areas on North Key Largo which should be preserved, restored and developed. The HCP includes a number of different components, including: a management plan for the habitat, an infrastructure plan, development guidelines, provisions for water quality and offshore management, and a financing plan.

The implementation of the HCP will require compliance with NEPA for any federal actions, and may include the development and enforcement of various agreements regarding the management of the conserved habitat, the pooling or purchase of lands for clustering of development and transfers of development rights.

B.
THE STUDY AREA

North Key Largo, the study area, is that area or part of Key Largo which is located between the junction of State Road 905 and U.S. 1 and the Dade County border at Angel Fish Creek. The study area is approximately 12 miles in length and 1/2 miles in width. A single two-lane road, State Road 905, runs along the center of the Key from its intersection with U.S. 1 to the private gate at the Ocean Reef Yacht Club. The study area lies between the two access routes to the mainland from the Florida Keys. To the southwest is the U.S. 1 Corridor over Jewfish Creek and to the northeast, immediately to the south of the Ocean Reef Yacht Club, is the Card Sound Bridge Road.

North Key Largo is largely undeveloped. The area, as viewed in profile from the Atlantic to the Gulf side, is typified by mature fringing mangroves along the Atlantic Coast with a

transitional wetland zone vegetated with buttonwood and marsh grasses. Upland of the transition zone is a tropical hardwood hammock characterized by mature canopy trees with over 30 years of growth. To the west or bay side from the tropical hardwood hammocks are mangrove wetlands, usually quite expansive, with large areas that are tidally flushed only on an intermittent basis. Immediately at the bayfront is another strand of fringing mangroves of 30 or more feet in height.

The landscape of North Key Largo is dominated by the expansive tropical hardwood hammocks transected by State Road 905. These forests, largely undisturbed, are distinctive in a number of ways. First, they are typical of a forest type that was previously widely distributed throughout South Florida, but has been almost eliminated by growth and development. Currently, the Florida Keys contain the only remaining substantial hammock communities, with the most viable examples remaining on North Key Largo. Second, the hardwood hammocks in North Key Largo serve as an important habitat for a variety of plants and animal species because the large undisturbed acreage provides sufficient area for effective propagation and reproduction. Third, the hammocks in their natural condition represent a distinctive visual resource not duplicated elsewhere in the United States. Finally, the trees themselves represent an impressive expression of the adaptive capacity of natural systems because of the unique way in which the hammocks have developed on what is essentially a soil-less Key.

C.
PLANNING OPPORTUNITIES AND CONSTRAINTS

Planning Opportunities

The land ownership in the North Key Largo study area is comprised of both private holdings and State and federal lands. Excluding the lands which have been designated for acquisition by the U.S. Fish and Wildlife Service for the Crocodile Lake National Wildlife Refuge and lands acquired or to be acquired by the State for the New Mahogany Hammock State Park, the remaining property on Key Largo is privately held by approximately 53 individual landowners. These individual property holdings range from parcels of several acres to parcels of several hundred acres. Additionally, these parcels vary from lands which contain both undisturbed and altered lands (e.g. Ocean Forest) to lands which may be totally scarified (e.g., Carysfort) or totally undisturbed.

One of the key features and constraints of land use planning on North Key Largo is the limitation on access, both surface and ocean. There are approximately four deep-water channels on the ocean side of North Key Largo and three navigational

channels located on the bay, or Card Sound side. Because water access is an important factor with respect to any development on Key Largo it may be appropriate to cluster development on those lands with existing water access channels. Some expansion of the access to existing channels may be appropriate where it does not entail dredging on state-owned submerged lands and will not result in an adverse impact on water quality. However, significant expansion of ocean access is constrained by both the regulatory framework and by tidal hydraulic characteristics and ocean bathymetry on the east side of the Key.

In order to properly assess the planning opportunities that are presented by the land uses on Key Largo, an important element is the identification and evaluation of habitat areas for the various species of concern on Key Largo.

Planning Constraints

There are certain basic habitat protection or development considerations which must be kept in mind in planning for North Key Largo. Of primary importance is reconciliation of both wildlife and development concerns and assurance that the species of concern are adequately protected. The following list of specific biological and cultural considerations was developed facilitate and to focus discussion on the HCP planning framework.

1. BASIC ELEMENTS

   a. Consistency with and support of the Monroe County Comprehensive Plan and other regulatory requirements.

   b. Provision of a basis for a detailed implementation program which is a feasible alternative and, on balance, protective of the Key Largo resources.

   c. Consideration of landowner expectations consistent with other objectives.

   d. Formulation of the HCP to provide functional and financial incentives to support long-term habitat maintenance and enhancement.

2. SPECIFIC CONSIDERATIONS

   a. Biological/Physical Elements

      (1)Provision for the survival and recovery of endangered species.

(2)Provision for acceptable levels of other wildlife to maintain the long-term integrity of the Key Largo ecosystem.

(3)Minimization of the loss of hardwood hammock and wetlands.

(4)Maintenance of largest possible contiguous hammock areas.

(5)Maintenance of corridors between existing hammock areas.

(6)Minimization of length of edges between development and habitat.

(7)Provision of appropriate and effective buffers between habitat and development.

(8)Provision for effective long-term monitoring of habitat (e.g., prevention of poaching, pesticide controls).

(9)Development of habitat management strategies which maximize predictability of success.

(10)Utilization of native trees and shrubs for landscape purposes.

b. Cultural Elements

(1)Maximization of cost effectiveness of HCP implementation actions.

(2)Provision of incentives for development to functionally and economically support habitat management both on and offshore.

(3)Provision for high value, high quality development consistent with market demand and economics to support habitat management objectives.

(4)Consideration of regional context -- national parks and private sector area uses.

(5)Provision for controlled public access to area.

(6)Optimization of aesthetic appeal of development by minimizing visual impact of structures, etc. from external view sources.

(7)Minimization of traffic impacts.

(8)Minimization of adverse fiscal impacts to the public.

(9)Consideration of perspectives of local citizens and Keys residents.

(10)Clustering of development near or adjacent to existing development.

D.
THE PROTOTYPES

INTRODUCTION

The habitat conservation planning process for North Key Largo was developed on an assessment of alternative management strategies for future development. The alternatives available were an infinite number of points along a continuum from no development of any kind within the Study Area to on-site development of every parcel of land. Given the purpose and objective of the effort, the Study Committee selected three points along the continuum for evaluation during the planning process:

- no development on-site
- development of all parcels of land in the study area.
- development clustered at discrete locations

It was assumed that the range of environmental, economic and social impacts that would result from implementation of any strategy along the described continuum was fairly illustrated by these three prototypes.

PROTOTYPE A
NO FURTHER DEVELOPMENT

Prototype A contemplated that no further development would take place in North Key Largo except for that development allocated to the Ocean Reef Yacht Club by the Monroe County Comprehensive Plan and the Port Bougainville and Garden Cove DRI development orders. The Study Committee identified two methods by which this management strategy could be achieved -- acquisition of all lands for conservation purposes or transfer of development rights to suitable parcels of land outside the Study Area.

Prototype A was a response to the perceived sensitivity of North Key Largo to human perturbation and the idea that there are certain irreconcilable conflicts between development and the resource values of the area.

One perspective of the area is that North Key Largo exists as an "inholding" surrounded by lands that have been acquired, authorized for purchase, or designated by government as preservation areas. North of the Study Area lies Biscayne National Park. To the east, is the John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary. The western side of Key Largo is almost entirely included within the boundary of the Crocodile Lake National Wildlife Refuge, which contains approximately 6800 acres of land which will eventually be purchased by the federal government. West of Crocodile Lake National Wildlife Refuge lie submerged lands owned and designated for preservation by the State of Florida. Further to the west and north lies Everglades National Park.

The Florida Natural Areas Inventory, a joint project of the Nature Conservancy and the Florida Department of Natural Resources, has developed a preliminary inventory of the North Key Largo Area. The Natural Areas Inventory has identified a total of 5 natural communities, 21 different plant species, and 10 different animal species which are either rare, endangered, threatened, or of special concern. 118 "element occurrence records" have been mapped in the hammocks east of SR 905. This is an extraordinarily high number, both of elements and element occurrence records in an area this size, when compared to data so far gathered by the inventory from the entire State.

As an "inholding" in a large area of lands already preserved, development of the remaining natural lands on North Key Largo and the lands that have been impacted but not yet developed presents environmental and management problems that go beyond the direct impacts of site disturbance.

If an urban or suburban community must be maintained in the middle of what is effectively a park or preserve, that requirement places limitations on the management and preservation of surrounding areas. An example of the effects from developed inholdings are the impacts of mosquito spraying, road kills, limitation of options for public access to shoreline areas, limitations on the ability of public land managers to close areas for management purposes, and the introduction of domestic pets that escape and do harm to wildlife.

Prototype A eliminates the need for additional public services by local government to serve the Study Area, and would help preserve the hurricane evacuation capacity of SR 905, Card Sound Road and U.S. 1 for use by residents of the areas south and west of North Key Largo.

TRANSFERABLE DEVELOPMENT RIGHTS

The first implementation strategy for Prototype A contemplated that the right to develop a specified number of dwel-

ling units will be allocated to vacant parcels of land in the Study Area. The use of those rights however, would be limited to transfer to identified receiver sites outside of the Study Area. The County's Comprehensive Plan allows dwelling units be freely transferable from one parcel to another so long as the receiver parcel is suitable for development and the number of units transferred to the site does not exceed a specified maximum designed to protect the character of existing neighborhoods.

The expectation is that the owners of TDRs would use their rights in a number of ways -- outright sale of TDRs, transfer to non-contiguous parcels owned by a TDR owner, or a joint venture with the owner of a parcel of land designated as an appropriate receiver site where the TDR owner's contribution to the venture is his TDRs.

ACQUISITION

This implementation strategy for Prototype A contemplated that all lands in the study area, or the development rights attached to those lands, would be acquired by one or more public or conservation agencies.

Currently, the State of Florida is in the process of buying lands on North Key Largo under the Conservation and Recreation Lands Trust Fund (C.A.R.L.). To date, over 800 acres just south of the Ocean Reef Club have been purchased for the New Mahogany Hammock State Park. Purchase of additional lands within the current boundaries of the C.A.R.L. project is being pursued, and is a high priority objective of the Division of State Lands.

On March 21, 1986, the C.A.R.L. Committee added approximately 1400 acres of lands to the C.A.R.L. acquisition program, beginning at the southern boundary of the current C.A.R.L. project, and extending south to just north of the Port Bougainville development. Also included in this expansion of the North Key Largo C.A.R.L. project are six tracts of submerged lands previously conveyed out of public ownership prior to the development of policies restricting such actions of government. Combined with the currently authorized C.A.R.L. project, the addition results in a need for the acquisition of over 2100 acres by the State.

This expanded C.A.R.L. acquisition project includes proposed purchase of sites that have previously suffered impacts from development activities (such as Carysfort, Ocean Forest, and Largo Beach & Tennis Club) in addition to undisturbed acreage. The purpose is to facilitate elimination of the secondary impacts from development that might occur on those tracts, to provide sites for future public recreation activities such as marina access to Pennekamp park for the public under controlled conditions, and to facilitate environmental restoration of disturbed

sites that have potential for recovery from pre-development activity damage. Another very important reason for including these parcels is to create a contiguous pattern of public ownership to facilitate the practical management of the area as a unit, most likely as an addition to the existing John Pennekamp State Park.

In addition to the payment of cash for land, other options are available to the State and federal government in bringing about acquisition of the lands described above. State and/or federal surplus lands could be offered in exchange, or other methods offering tax advantages, such as bargain sales, could be used.

Sources of funding for outright purchase include; the C.A.R.L. fund; Save Our Coast; Save Our Beaches; a special act of the legislature establishing a taxing district; a general appropriation to the C.A.R.L. fund; a one time increase in the C.A.R.L. fund for the purpose of this project by adjustment for one year of the distribution of the severance tax; a special sales tax increase earmarked for the acquisition, and similar methods.

A significant implication of the acquisition alternative is that the value of the property acquired would be removed from the County's tax roll. In contrast, the TDR alternative would not involve a net loss of value because the assessed valuation would be transferred to the receiver site.

Prototype B
Parcel by Parcel Development

This prototype assumed that approximately 3,500 additional dwelling units (DUs) would be built in the North Key Largo Study Area in addition to Port Bougainville and the Ocean Reef Club. The prototype also assumed that development would occur according to existing land ownership patterns -- excluding those lands which have been designated for acquisition by the U.S. Fish and Wildlife Service for the Crocodile Lake National Wildlife Refuge and those lands which have been determined to be "wetlands" under the Clean Water Act. (It is assumed that these areas will be acquired by the public sector.) Prototype B therefore provides for development on all disturbed and scarified lands as well as lands which may contain hardwood hammock stands and transitional habitat areas.

The dwelling units available to the Study Area would be allocated on an equitable basis reflecting the relative market values of various land types. Tidal mangroves would be allocated the fewest units per acre while mature hardwood hammocks would be allocated a relatively greater number of units. The use of the development rights would be strictly controlled by performance

standards designed to limit the adverse impact on habitat values. For example, structures in tidally influenced areas would be required to be elevated and development in hammocks would be clustered so as to limit the amount of disturbance. Restrictions on drives, roads, pets and insecticides would be required in order to reconcile the conflict between human activity and wildlife habitat. This prototype also included public facilities improvements, such as roads and sewer. In Study Committee discussion, this prototype was eliminated as unacceptable due to its extreme impact on the wildlife and critical habitats in the Study Area.

Prototype C
Cluster Development

Prototype C assumes that 3,500 additional dwelling units will be built in the North Key Largo Study Area. Unlike Prototype B, however, development will not necessarily occur in accordance with existing land ownership patterns. Rather, development will be clustered and concentrated in those areas which are identified as the most appropriate for development due to their higher economic value for development purposes, adjacency to existing development, lesser adverse impact on wildlife habitat (such as altered lands or lower value hardwood hammocks) and the ease with which public services can be provided locations which will minimize adverse impacts on wildlife habitat and maximize the value of proposed development. In this way, habitats would be protected and enhanced by concentrating development in locations surrounded by large, contiguous areas of inter-connected habitat.

The criteria for identifying development sites under the clustered prototype included:

1) the existing condition of a site (scarified, disturbed or native);

2) the availability of public facilities;

3) the impact of development at the site on the habitat;

4) adjacency to existing development; and

5) access to nearshore waters.

If development was to be clustered to sites within the Study Area it was vital that the cluster sites not adversely effect any of the endangered species. Lands which were partially developed -- that is, subdivisions with some existing homes, -- represented the most obvious sites for future clustered development. The Monroe County existing land use maps indicate that

there are 49 acres of such land in the Study Area outside the Ocean Reef Yacht Club.

Obviously, lands that have already been scarified represent lands that are more appropriate for development, particularly if the substrate has been modified. According to Monroe County's existing land use maps there are approximately 131 acres of land in the Study Area that have been identified as "scarified."

Lands that are currently in disturbed states may also be suitable for clustered development though disturbed lands are likely to be capable of natural succession and may in fact play an important role in providing habitat diversity. The Schaus Swallowtail's dependency on torchwood is aided by successional phases that allow torchwood to establish itself in open flight areas.

The balance of lands in North Key Largo remain in a native condition and portions of them are presumably inappropriate for development except that a few isolated hammock areas may not be suitable as long-term rodent habitat. Tropical hardwood hammocks are the habitat of the woodrat, the cotton mouse and the swallowtail and each species is sensitive to disturbance. Mangroves and the associated transitional zones buffer the hardwood hammock from sea breezes and storm wind and water, as well as serving as a vital food source and habitat for important wildlife species. The loss of mangroves on the windward side of a tropical hardwood hammock could result in the desiccation and ultimate destruction of the hammock. The shallow mangroves areas near the intersection of the Card Sound Bridge Road and State Road 905 are home to the American Crocodile, an animal that is very sensitive to human presence.

The cluster prototype involved more than identification of suitable cluster sites because the provision of required public facilities also involved impacts beyond the boundaries of selected sites.

Finally, in order to meet the requirements for a section 10(a) permit, the cluster prototype will have to demonstrate:

(a) Provision of conserved habitat;

(b) Maintenance, management, improvement and restoration of conserved habitat;

(c) Necessary funding for conservation programs; and

(d) Assurances to protect environmental resources (e.g., to protect against adverse impacts on the coral reef), as well as development rights to be provided to the private sector.

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HABITAT CONSERVATION PLAN

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CHAPTER I.
INTRODUCTION

The material which follows in this volume is a compilation of what is known about the natural systems and built environment of North Key Largo. This material was assembled in part from the background data commissioned by Monroe County in its comprehensive planning process. Additional information on the endangered species was commissioned by the Study Committee using funds provided by private interests. This information forms the foundation for the policies and assumptions upon which the Habitat Conservation Plan is based.

CHAPTER II.
THE MANAGEMENT AREA

A.
THE NATURAL ENVIRONMENT

1.
Geomorphological and Climatic Overview of the Florida Keys

Discovered by Ponce de Leon on May 12, 1513, the Florida Keys have always fascinated those who have come in contact with them. Lying along the New World trade routes and blessed with a semi-tropical climate, their history has been intimately tied to the ocean from which they arose.

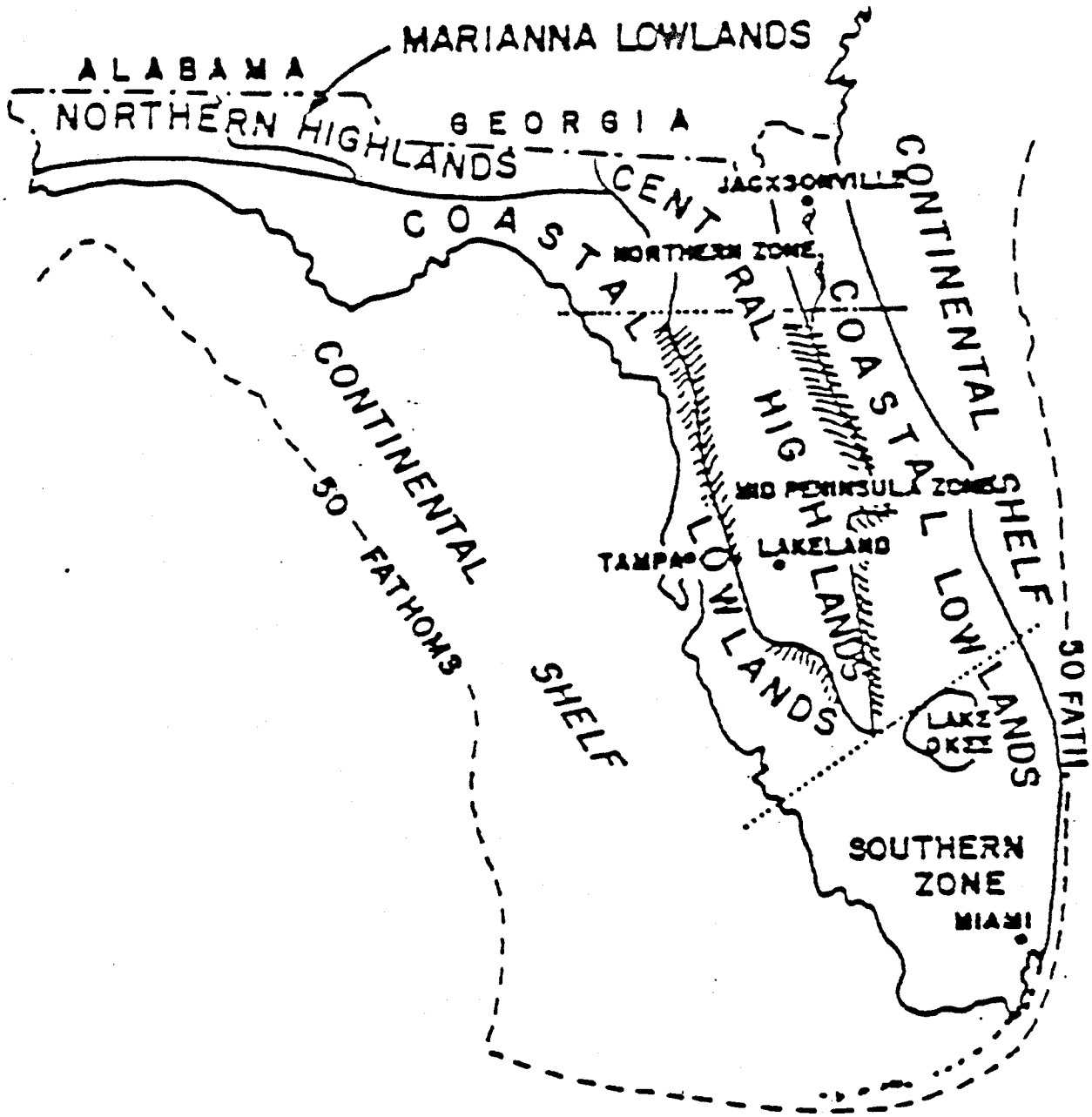
The Florida Keys proper are an elongate, arcuate chain of low-lying islands over 220 miles in length, extending from the southeastern tip of the Florida Peninsula, more properly called the Florida Plateau or Florida Platform. They extend from Soldier Key at the northernmost end of the chain, to the Dry Tortugas to the south and west at the other end. They are bounded by the Straits of Florida on the Atlantic side and separated from the mainland by Biscayne Bay, Barnes Sound, Blackwater Sound and Florida Bay (White, 1970; Brooks, 1982).

Physiographically, the Keys belong to what has been called the Southern Zone of the Coastal Lowlands by the Florida Geological Survey (See Figure 1), also referred to as the Gold Coast and Florida Bay (Brooks, 1982). This area lies south and southeast of Lake Okeechobee, is primarily underlain by Pleistocene limestones, and is characterized by low relief, poor drainage and extensive areas of coastal mangrove swamps (Brooks, 1982).

The Upper Keys

As their other name implies, the Coral Reef Keys are a linear chain of islands made up primarily of limestone coral rock. The main axis of the islands lies parallel to the axis of the chain. They extend from Soldier Key to the North, to the lower (southern) end of the Big Pine Key. On their seaward side lies a well developed reef tract composed of an outer fringe reef that borders the inner edge of the narrow continental shelf that averages a mere 4 miles in width. Between the Keys and this relatively continuous outer fringe reef, shallower banks and deeper channels dotted with patch reefs run parallel to the islands. These living reefs, unique in the United States, are best developed in the Upper Keys area. Because corals are exceedingly sensitive to turbidity, their development is favored by the long orientation of the islands and the limited number of channels between them. This particularly fortunate combination of circumstances acts to block the influx of carbonate muds from the bays

Figure 1:
PHYSIOGRAPHIC DIVISIONS OF THE FLORIDA PENINSULA TIDE
FLORIDA GEOGRAPHICAL SURVEY



and prevents silting of the reef tract (Brooks, 1982; Hoffmeister, 1974).

(a) Geology and Stratigraphy

Little is known of the earliest history of the southern part of the State of Florida, as data are notably absent due to the paucity of deep wells. It is known that basement rocks in the central and northern part of the state range in depth from 3,000 feet in the northern part of the state to some 12,000 feet near Lake Okeechobee. In character they resemble rocks associated with the Appalachians. In the southern part of the state, however, the deepest non-sedimentary rocks penetrated are basaltic submarine volcanics (See Figure 3) (Bass, 1969). They are overlain by a wedge of sedimentary rocks that rapidly thickens southward and exceeds a thickness of 20,000 feet in the Keys. It is noteworthy that such volcanics are commonly associated with areas where the crustal plates separate. Reconstructions of Pangea, the giant land mass that existed before the present continents assumed their modern shape and location, show that the boundary between North America and Africa crossed the tip of Florida. If such reconstructions are correct, the abrupt deepening of the basement rocks in South Florida would mark the line of separation between these two continents when Pangea broke up. The presence of submarine volcanics would therefore confirm such an interpretation. In any case, it is generally accepted that South Florida is an area where sediments prograded over oceanic crust. (See Figure 4) (Shurbet, 1968)

Although Mesozoic sediments represent thicknesses well in excess of 10,000 feet (Puri and Vernon, 1964), only the more recent Cenozoic sediments have a direct bearing on the history and the formation of the Keys. Of these, the most important are the sediments deposited since Miocene time. Although these sediments give us an excellent record of the past environments of South Florida, much controversy still surrounds their age and in some cases their exact stratigraphic relationships. Reconstruction of the past is further complicated by the fact that the relationship between land and sea has not been static. (See Figure 5)

It is well known that the advent of glaciation in higher latitudes affected sea level. During glacial periods, when water accumulates on land in the form of ice, sea level drops. Conversely, during periods of climatic amelioration, sea level rises as water is returned to the sea. It is generally estimated that if all the water presently tied up in glaciers were returned to the oceans, sea level would rise by some 200 feet. Conversely, during glacial maxima, sea level dropped by as much as 350 below present level. It is easy to see that an area such as the Keys, which lies but a few feet above present sea level, would be markedly affected by the 500+ foot oscillations that have affected the world's coasts since Middle Tertiary Miocene times. These fluctuations are relatively rapid when measured against geologic

time. Indications are that sea level has risen some 8 to 10 inches during this past century alone. Other evidence, such as the presence of peat under Crane Key 4 to 10 feet below present sea level indicates a much lower sea level a mere 4000 years ago. Some 20,000 years ago, sea level may have been as low as 450 feet below present level (See Figure 6). Although the general sequence of events is relatively clear, there is still considerable argument as to the precise age of a specific event (Brooks, 1973; Alexander, 1974; Fairbrige, 1974).

The Key Largo Limestone

The Key Largo Limestone outcrops at the surface from Soldier Key to the southernmost end of Big Pine Key, over a distance of 110 miles. However, subsurface drillings indicate that it originally extended over twice its exposed length, from Miami to the Dry Tortugas. It varies in thickness from 70 to over 170 feet. It is a fossil coral reef whose main structure is a network of coral heads with intervening spaces filled with detrital reef material. Star coral, and less commonly brain corals, are the dominant species found in the exposed Key Largo Limestone indicating that the reef presently visible was once a patch reef. Drilling seaward of the presently exposed part of the Key Largo Limestone reveals the presence of moosehorn coral, a species characteristic of present fringe reefs. No doubt the lowering of the sea which allowed cementation of the Miami Limestone also killed the reef as it emerged. The subsequent rise of the sea, which reshaped the oolitic limestone of the lower Keys, also destroyed most of the outer fringe reef. Only the inner patch reef is visible today and forms the backbone of the upper Keys. (See Figure 7.)

The Key Largo Limestone is a very porous coralline limestone. It is riddled with solution features and voids, allowing water ready passage, both vertically and horizontally. Although potentially an excellent aquifer, it contains very little fresh water because its permeability allows ready outflow (Hoffmeister and Multer, 1968; Hoffmeister, 1974; Parker, et al., 1955).

(b) Groundwater in the Keys

Although the Miami area has a relatively ample supply of fresh water (albeit increasingly depleted by ever-growing demand), such is not the case in the Keys despite similar regional geology. Surrounded as they are by salt water, their fresh water resources are meager at best, and too often nonexistent. Fresh water lenses of the Biscayne Aquifer exist primarily on Big Pine Key and Key West, as well as on No Name, Cudjoe and Upper Sugar-

Figure 3:
BASEMENT MAP OF THE GULF OF MEXICO
AND ADJOINING STATES (BROOKS - 1972)

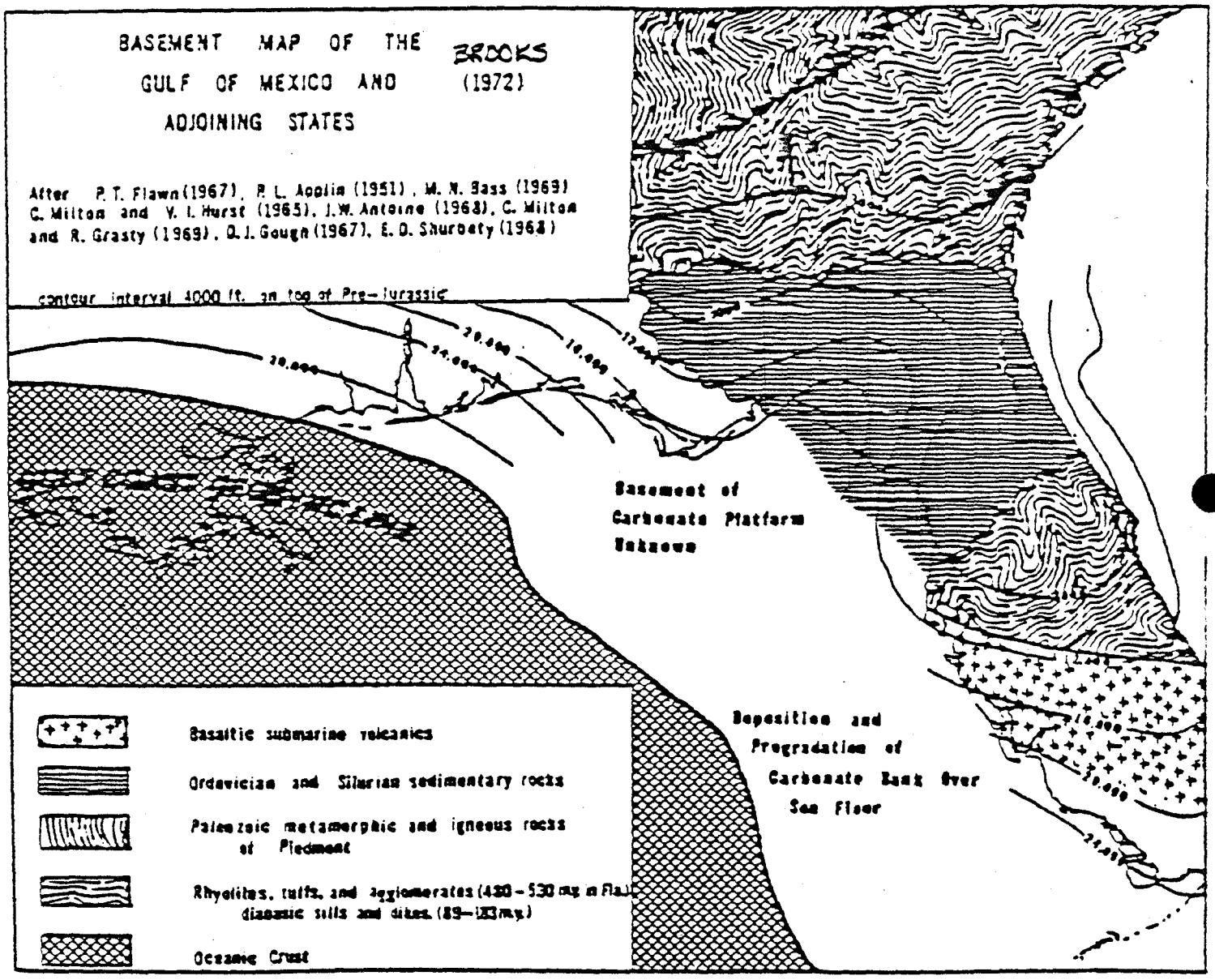


Figure 4:
GENERALIZED GEOLOGIC CROSS SECTION
THROUGH FLORIDA (Fla. State Geol. Surv. Bull. 5).

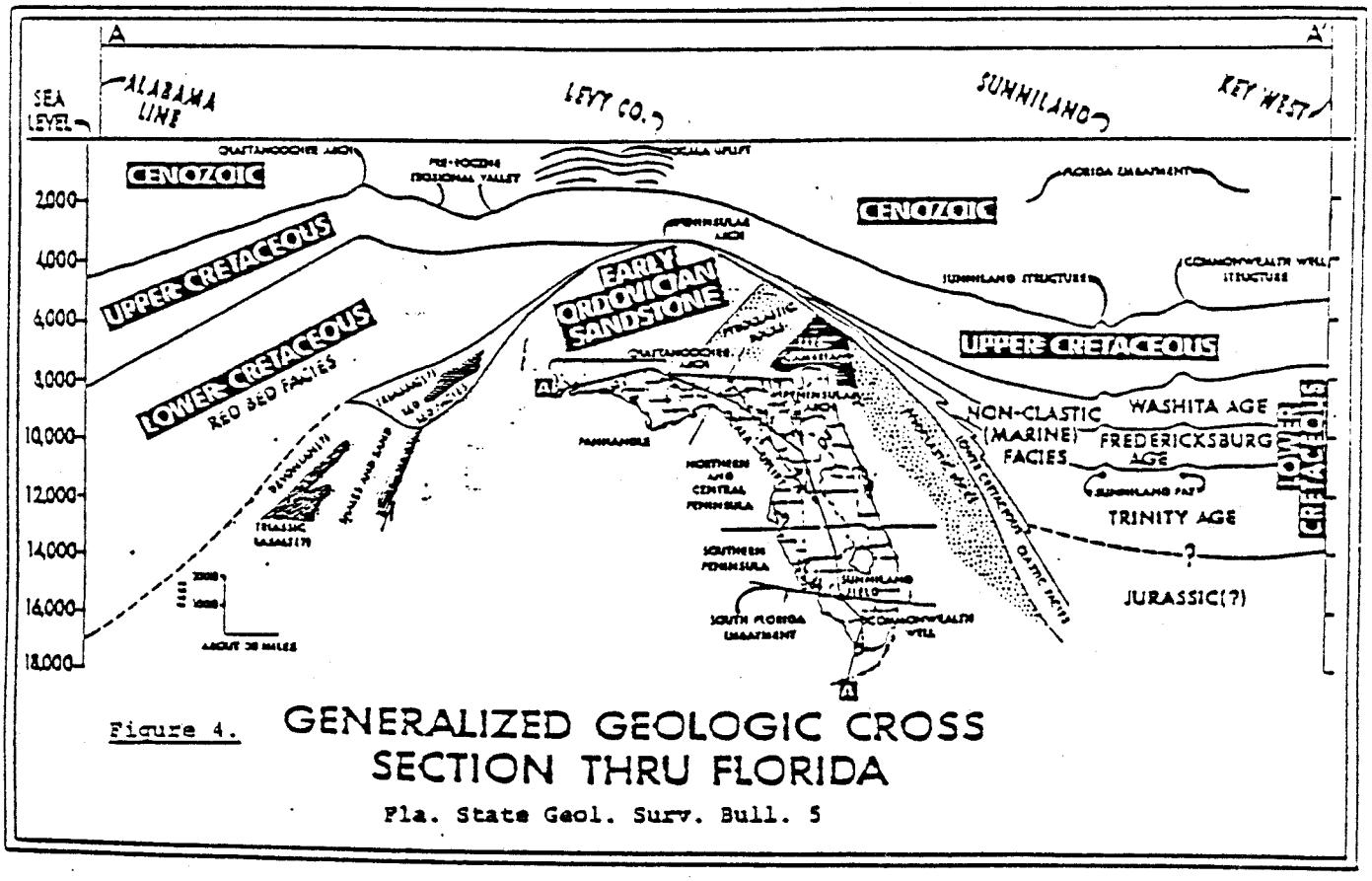


Figure 4. GENERALIZED GEOLOGIC CROSS SECTION THRU FLORIDA

Fla. State Geol. Surv. Bull. 5

Figure 5:
STRATIGRAPHIC RELATIONSHIP
BETWEEN THE UNITS (Puri and Vernon, 1964)

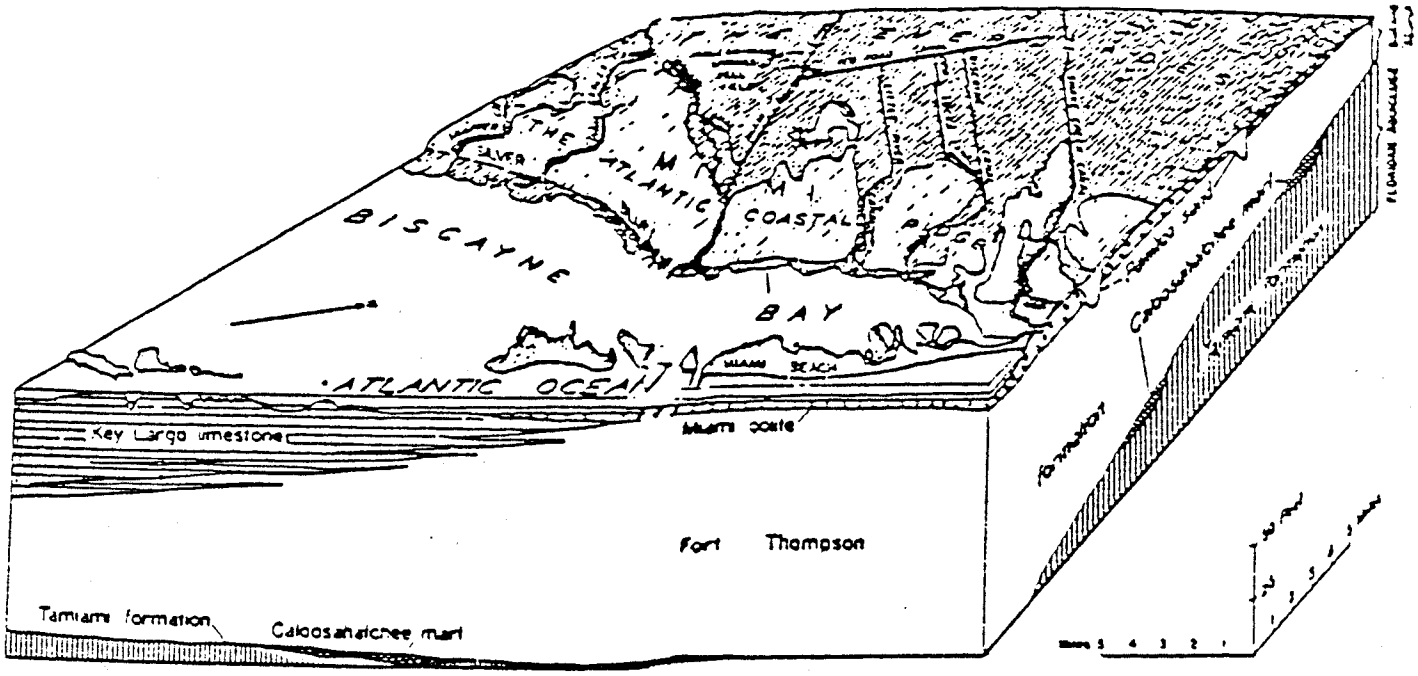


Figure 6:
GLACIAL EUSTATIC SEA LEVEL CHRONOLOGY BASED
UPON STRATIGRAPHIC EVIDENCE IN FLORIDA (Brooks, 1968, 1972)

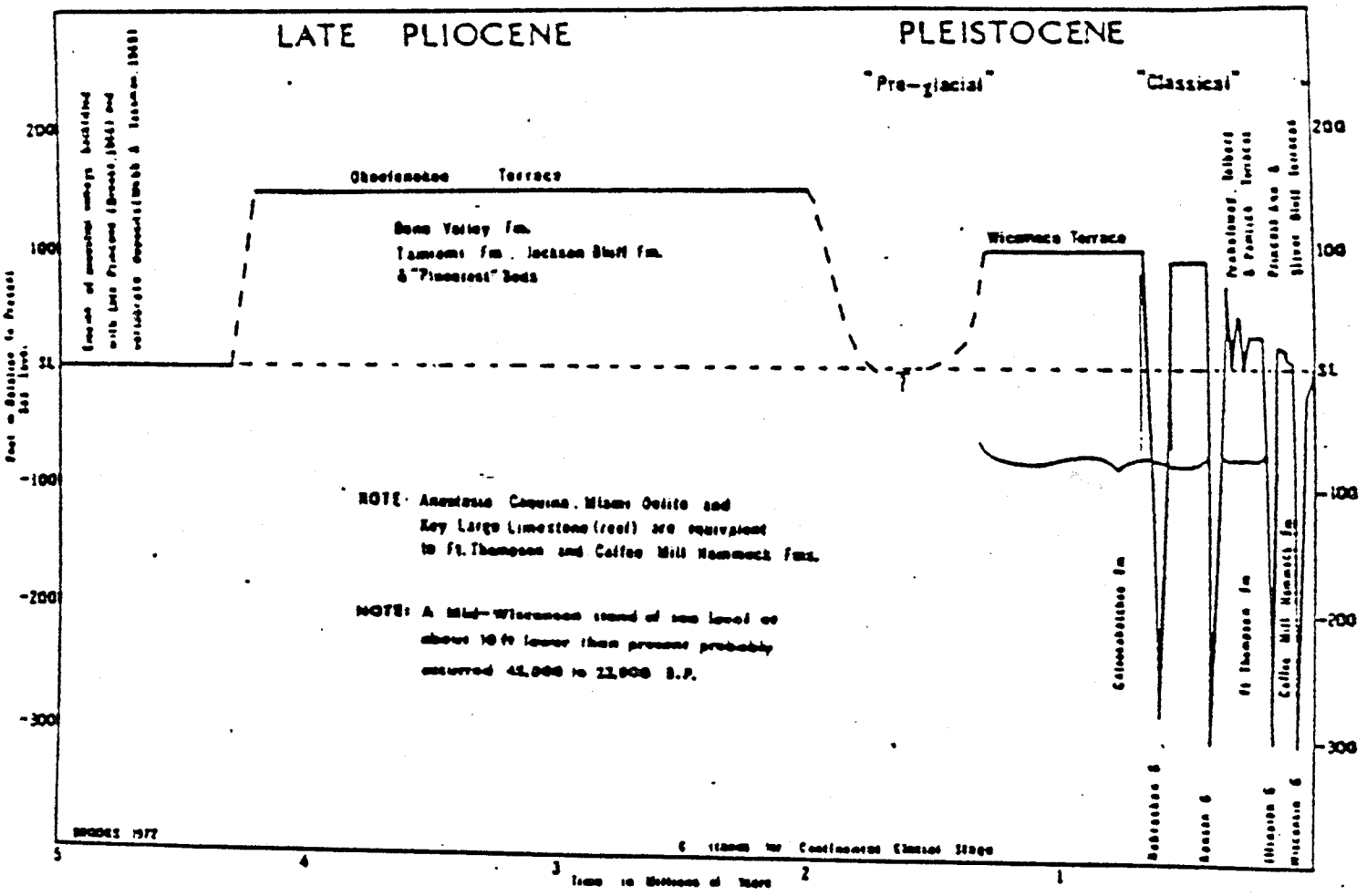
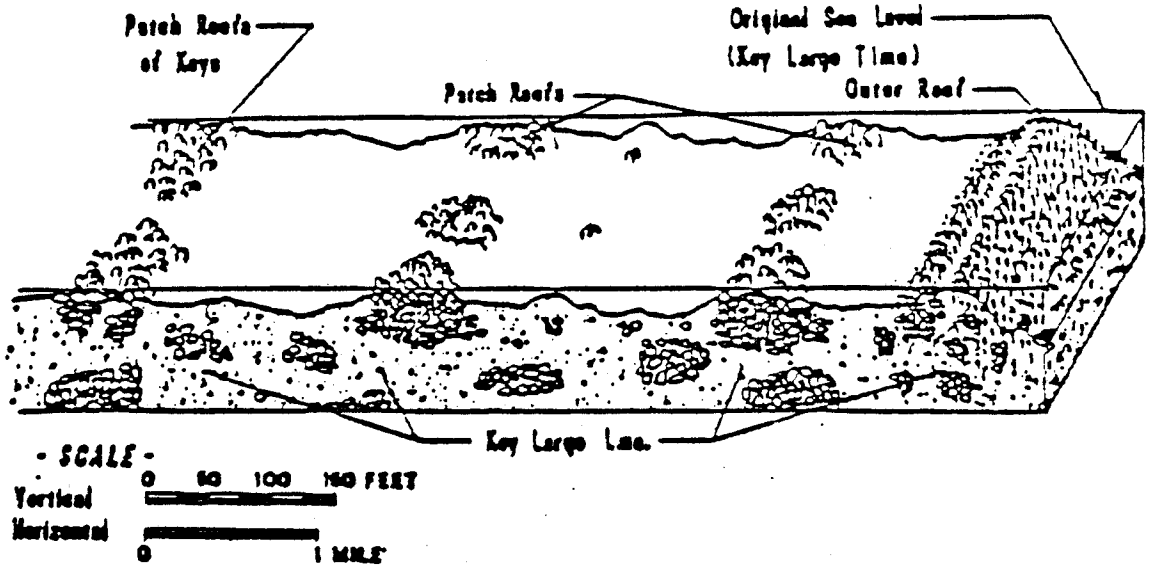
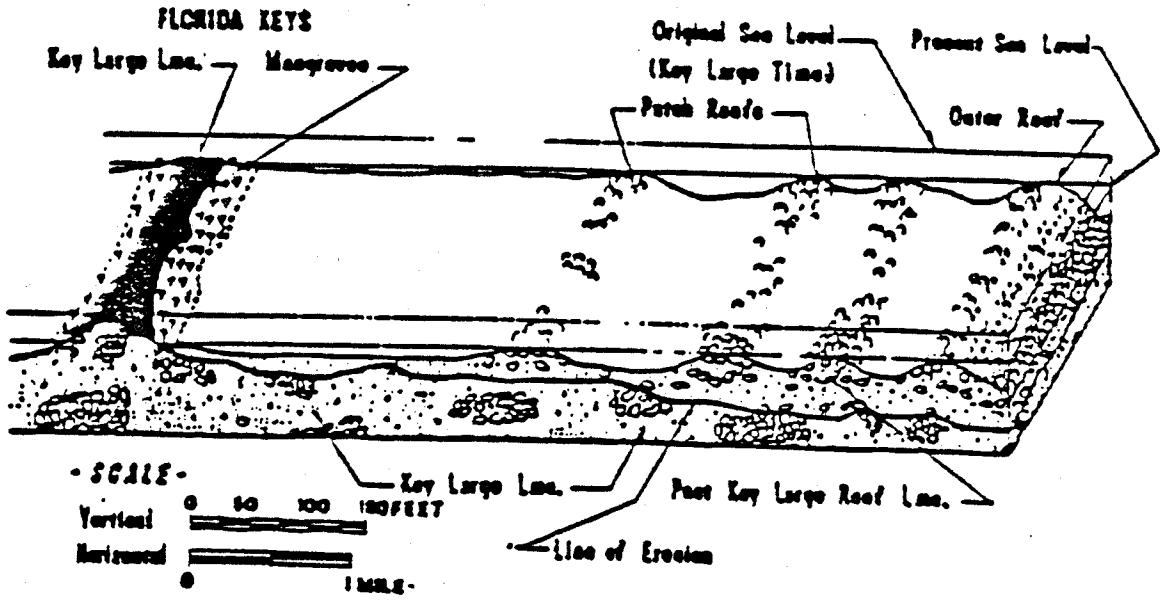


Figure 7:
A RECONSTRUCTION OF ENVIRONMENT DURING KEY LARGO LIMESTONE FORMATION TIME (above);
PRESENT CONDITIONS (below) (Hoffmeister, 1974)





loaf Keys. Dependent on rainfall for recharge, local supplies are further limited by runoff, evaporation and transpiration and outflow from the aquifer (Parker, et al., 1955; Klein, 1970; Hanson, 1980).

Although the Upper Keys receive more rainfall than the Lower Keys, they have virtually no fresh water supplies. Because the voids in the underlying Key Largo Limestone are interconnected horizontally, percolating rainwater is not confined laterally, resulting in increased outflow. For the same reason, saltwater readily rises and passes through the aquifer in response to tidal influences. This results in increased mixing and dissipation of the fresh water (Parker, et al., 1955; Chesher, 1974).

Despite the presence of some fresh water lenses, it is not expected that groundwater supplies of the Keys will ever provide a significant amount of fresh water. Nevertheless, large withdrawals would severely impact the limited supply available with concommitant salt water intrusions. Given the character of Karst substrates, it is reasonable to assume that there exist at least direct connections between surficial waters and groundwater lenses. Thus, any diminution of these lenses is likely to reduce the availability of fresh water to the flora of wetland systems and to the wildlife that utilizes these sites.

(c) Tides

Tides affect nearly one million acres of estuaries and tidelands in Florida, and their rise in daily and secular variations intimately affect natural ecosystems and human activities alike.

It has been known since antiquity that tides are linked to the motion of the sun and the moon. However, the basic explanation for tides, namely the interaction between the gravitational forces of the earth-moon-sun system, did not come forth until Newton's time. Because the moon is the closer body to the earth, its influence is preeminent. Bodies of water which face the moon are closer to it and therefore are subjected to greater forces. Being less rigid than the solid earth, the body of water facing the moon is subjected to greater acceleration than the remainder of the system and bulges towards the moon. Oceans on the opposite side of the earth, being farthest away, will experience a lower gravitational gradient than the earth and, experiencing less acceleration, will bulge away from the earth. Thus, interaction of gravitational forces will give rise to two bulges, once facing the moon, the other at its antipodes. As the moon passes a given point on the surface of the earth 50 minutes later each day, each point on the surface should experience two high tides and two low tides during each tidal day of 24 hours and 50 minutes.

The attraction of the sun, albeit weaker than that of the moon because of its greater distance from the earth, will

have a similar effect on bodies of water. Depending on the relative positions of the three bodies, the gravitational pull of the sun may reinforce that of the moon to cause the greater than normal tides called spring tides. During periods when they partially cancel each other, lower-than-average tides called neap tides occur.

These effects are further complicated by a host of other factors. Because the planetary bodies travel in elipses rather than circles, earth-sun and earth-moon distances vary continually. Furthermore, the angle between the earth's Equator and the sun varies by 47 degrees over a period of a year. Similarly, the moon's position will shift from 28.5 north to 28.5 south of the Equator over a period of a month. To complicate matters even further, tidal bulges are not free to move over the surface of the earth, as the various ocean basins are separated by continents. Further, tides in a given locality are affected not only by the gross topography (Gross, 1977). Once put into motion, the water in a particular basin will begin to oscillate with a frequency natural to that basin. Apparently, the natural frequency of the Gulf of Mexico is 24 hours. As such it naturally responds more readily to diurnal tidal forces and the Gulf is characterized by a diurnal regime of one high and one low tide per tidal day (Marmer, 1954). In contrast, the Atlantic basin exhibits two high tides and two low tides of nearly equal amplitude per tidal day. Such a regime is referred to as semi-diurnal (See Figure 8).

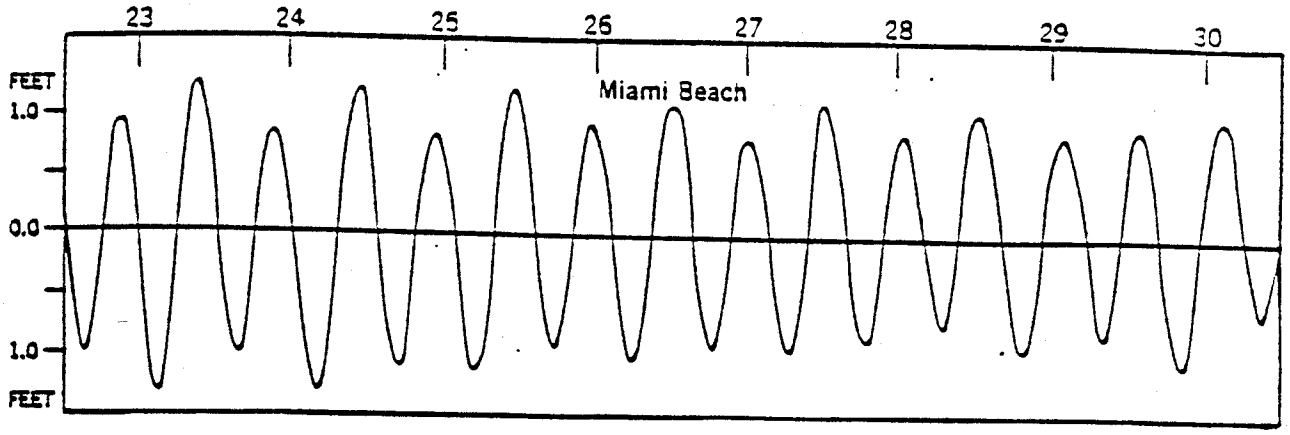
It is not surprising that Key West, lying as it does at the edge of both basins, will exhibit a mixed tide pattern (See Figure 10). Although there are two highs and lows per tidal day, they are of unequal amplitude. In the Keys proper, tides change along the length of Key Largo. North of Rodriguez Key they are of the semi-diurnal type and below they are classified as belonging to the mixed type. The amplitude of tides tends to be lower in low latitudes and indeed the tidal range at the Miami station is only on the order of 2.5 feet (Marmer, 1954; Provost, 1973). Furthermore, the tidal range along the continental slope break decreases southward along the Keys to Key West where it is on the order 1.1 feet (Provost, 1973).

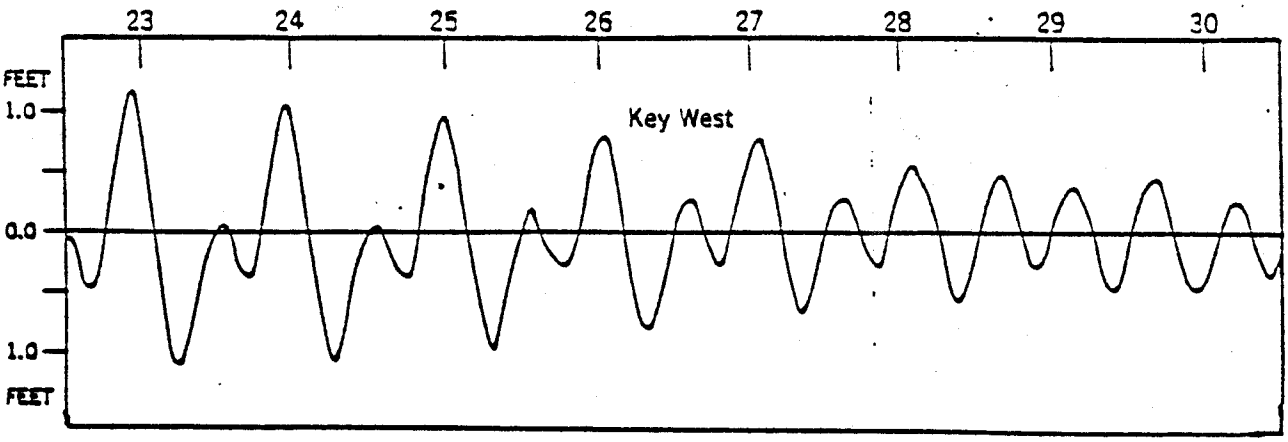
There is a marked delay in tides between the Atlantic and Florida Bay side of the Keys, a fact which is commonly attributed to friction (Enos, 1977). No doubt it is also related to local topography and to the characteristics of Florida Bay. Because it is a small shallow restricted basin, Florida Bay does not exhibit large tides; in fact, their amplitude is on the order of 0.5 feet, leading to a marked water gradient between the two sides of the Keys. Consequently, at high tide there is substantial water inflow into Florida Bay from the Atlantic. The magnitude of this difference is related to the number of openings between the two systems. In the Upper Keys where the islands act as a barrier, and few openings connect the Atlantic to Florida Bay, the water gradient is quite marked. In the Lower Keys where

the islands lie parallel to the tidal flow direction and where the openings are common, the gradient is much less (Enos, 1977).

As a direct consequence of the restricted interchange between Atlantic and northern Florida Bay waters, tidal flushing is of limited consequence, leading to restricted circulation and mixing. As a result, meteorological effects, such as wind induced mixing, evaporation, rainfall, and fresh water inflow have a greater effect on water parameters such as depth, salinity, and turbidity than do daily tides.

Figure 8:
TIDE CURVES, MIAMI BEACH
AND KEY WEST, JUNE 23-30, 1948 (Marmer, 1954)





Tidal amplitudes are also influenced by meteorological conditions. Changes in barometric pressure influence the height of the water column. Theoretical calculations indicate that tidal height may rise up to one foot for every one-inch decrease of barometric pressure. Even greater than barometric effects are changes in tides induced by the wind. In shallow areas, the wind may force a large amount of water against a coastline inducing not only a greater amplitude in the tides but also tidal currents as the water is forced to move laterally in response to the gravitational gradient. Both these effects are common during hurricanes where the tidal surges up to 25 feet have been recorded.

Throughout the Gulf of Mexico, annual variations in sea level are also superimposed upon the shorter-form fluctuations. In Key West, sea level is higher in October (+0.5') and lowest in March (-0.3'), resulting in an annual variation of 0.8' (Marmer, 1954). Such yearly fluctuations no doubt affect the water regime of many coastal habitats particularly on the shallower Florida Bay side of the Upper Keys while such direct effects as emergence or drowning are readily discernible. This yearly fluctuation also influences water depth, temperature, and salinity, as well as evaporation rates, fresh water mixing rate, and sediment deposition and circulation.

Lastly, tide amplitude is also affected by long range variations in sea level. Careful record-keeping indicates that amelioration of climate has led to an historical rise in sea level. Along the Atlantic Coast, sea level has crept up at the rate of one foot every 72-125 years, averaging approximately one foot per century. This rise seems slower in Key West where the average rise is closer to one foot in 143 years (Provost, 1973). Little is known, however, about the causes of these variations.

(d) Climate

Lying in the zone of the trade winds, the Keys experience a subtropical savanna type climate characterized by warm summers and mild dry winters (Bradley, 1972). The mean annual sunshine is 3,300 hours, ten percent more than the Florida peninsula to the north, and average daily solar energy reaching the Keys has been calculated at 447 langleys (Dames and Moore, 1978).

The mean annual temperature ranges from 77 degrees F in the Lower Keys to 76 degrees F in the Upper Keys. The mean temperature for January, the coldest month, is 69 degrees F, while August, the hottest month, has a mean of 84 degrees F (Thomas, 1974) (See Figure 9). One striking aspect of the isotherms is how closely they follow the coastline from the Dry Tortugas to Ft. Pierce. This is primarily due to the meliorative effect of the warm marine waters that bathe the Keys, and the presence of the warm Gulf Stream along the coast (Jordan, 1973).

Yearly rainfall in the Keys ranges from 35-45 inches, although it may be as little as 20 inches or as much as 60 inches in a given year. Most of the rainfall comes during the wet season, the summer months from May to October, and has a pronounced biomodal distribution (Thomas, 1974). Most of the rain falls during May, June, September and October (See Figures 10 and 11). During these months, the Keys lie in a low-pressure trough area between two anti-cyclonic cells. As this trough shifts into the Gulf during July and August, rainfall decreases. Thunderstorms are the primary source of water during the wet season. Ninety percent of the 60 to 80 storms that occur each year form during the wet season when approximately 35% of the days report thunderstorms, due in large part to convective processes (Jordan, 1973). As the moist, oceanic air heats up over the land during hot summer days, it becomes unstable and rises. Moisture condenses forming thunderstorms. This process is favored by the orientation of the Keys virtually at right angles to the prevailing easterlies. Occasionally, tropical cyclones will also add to the water budget of the Keys.

During the dry winter season, most of the rainfall is due to cold fronts, which pass over the area on the average of once a week. Winter rainfall, however, accounts for less than one third of the precipitation in the area (Thomas, 1974).

There is a net decrease in precipitation southward, presumably for two reasons. Winter cold fronts do not pass into the Lower Keys as often as they do in the Upper Keys. Further, convective thunderstorms do not develop as readily over small islands as they do over the mainland. This also accounts for the fact that the Lower Keys show less marked seasonal differences than the Upper Keys.

Figure 9:
MEAN TEMPERATURE FOR JANUARY AND AUGUST, (Thomas 1974)

MEAN TEMPERATURE FOR JANUARY AND AUGUST, (Thomas 1974)

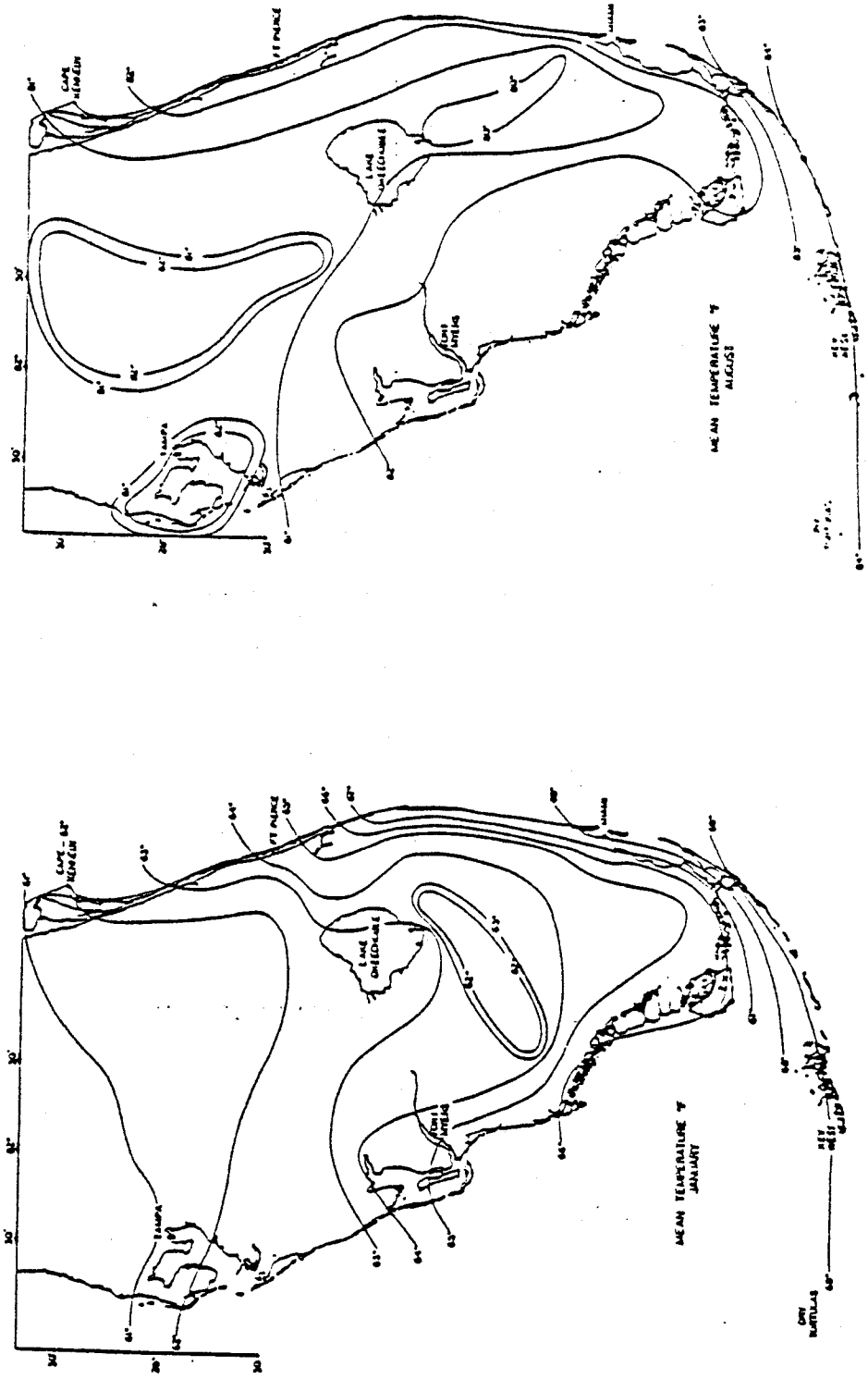


Figure 10:
AVERAGE ANNUAL RAINFALL IN INCHES (Thomas, 1974)

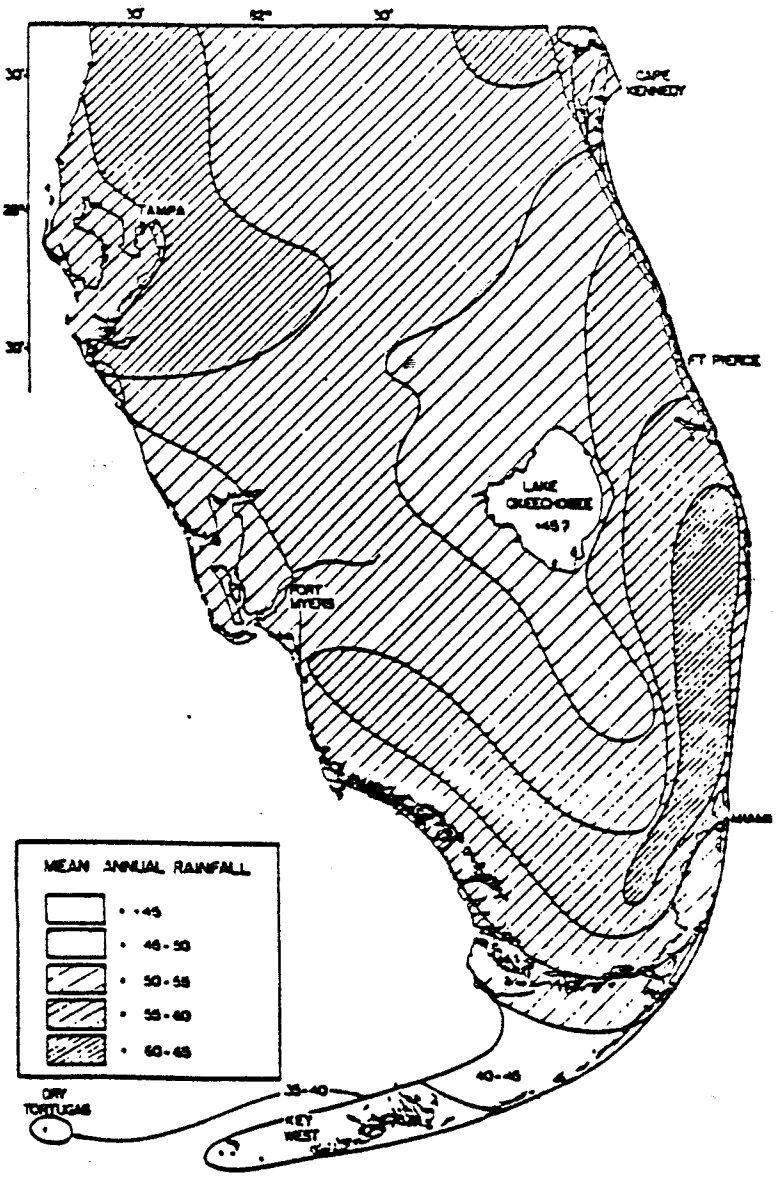
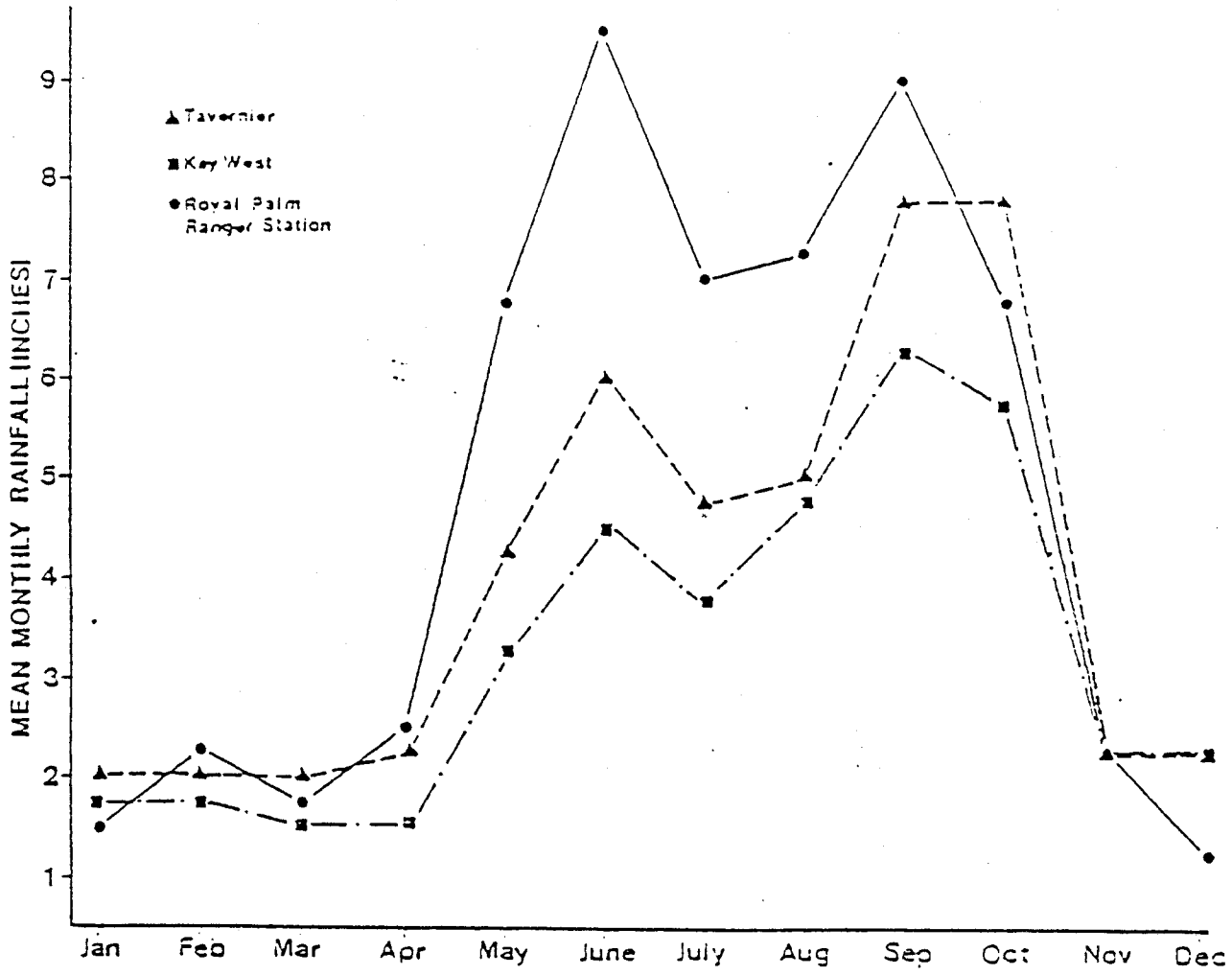


Figure 11:
AVERAGE MONTHLY RAINFALL FOR THREE REPRESENTATIVE STATIONS IN STUDY AREA (Schomer and Drew, 1982)



Winds are relatively mild, averaging 11-12 knots throughout the year, with highest winds occurring during the winter months (November through April) and decreasing during the summer, although wind velocities nearing 250 mph were associated with the great hurricane of 1935 (Jordan, 1974; Gentry, 1974). (See Figure 14) Because the Keys lie in the area of the trades, wind direction is generally easterly. An excellent synopsis of the general climate of the area can be found in Schomer and Drew (1982).

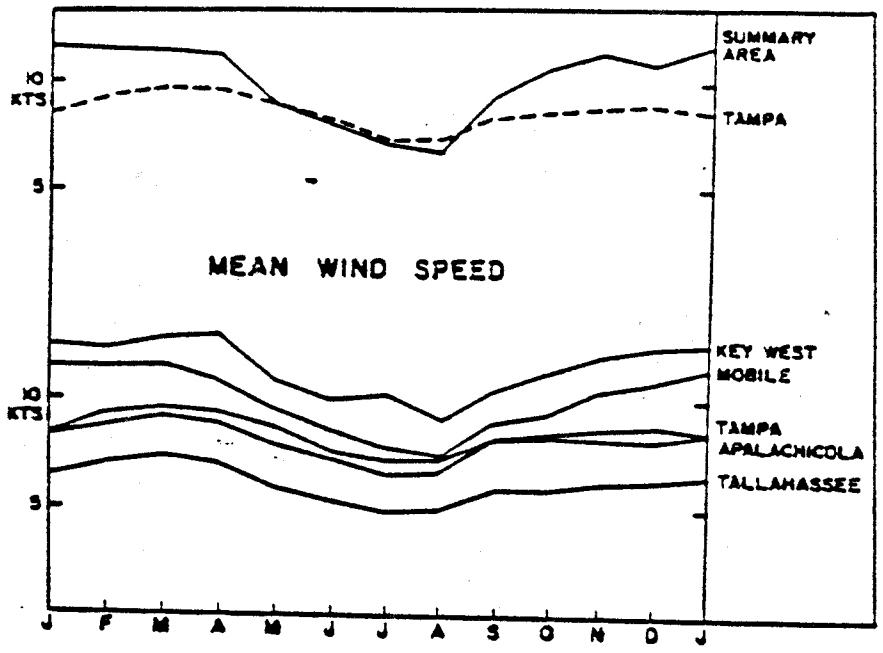
(e) Hurricanes

No climatic discussion would be valid without mentioning tropical cyclones. Almost invariably spawned in the latitudes from 5 to 20 degrees North, these areas of low pressure vary in intensity and degree of organization. Cyclones with poorly defined circulation and winds of less than 38 mph are called tropical disturbances or depressions. If the circulation pattern becomes closed and the maximum winds exceed 38 mph, the depression is reclassified as a tropical storm. When the maximum winds exceed 74 mph the storm becomes a hurricane. Should the maximum sustained winds exceed 125 mph, it is referred to as a great hurricane (Gentry, 1973).

Hurricanes commonly begin as a wave or disturbance in the trade winds. If this wave intensifies, a counterclockwise circulation cell begins. As it gains energy from the condensation of moisture carried upward in the center of circulation, the pattern intensifies into a tight spiral extending hundreds of miles outward from a central low pressure zone (called the eye) commonly 10 to 20 miles wide. In the eye, where pressures may be as low as 940 millibars, the winds are relatively calm (20 mph or less) and the sun may even break through the clouds. Virtually without transition as one leaves the eye, wind velocity jumps to over 200 mph in some of the great hurricanes. Torrential rains and severe thunderstorms ring the eye to heights of 40,000 feet and some 30 miles outward. Winds often reach 50 mph even 100 miles out from the eye, and the circulation system may extend over 300 miles from the center. Thus, a single storm may affect the entire Keys (Miller, 1971).

Since they depend on warm moist air for their energy supply, it is not surprising that these cyclones are most common during the summer months. In the area of the Keys, there were 38 hurricanes from 1901-1971 (Jordan, 1973). Nearly 80% occurred during the months of August, September and October, while the months of November through May accounted for only 10% of all the hurricanes. October alone accounted for 37% of these hurricanes. Similar data for the North Atlantic confirm this pattern. It should be noted that although yearly patterns are clear, no long range pattern has been detected.

Figure 14:
SEASONAL DISTRIBUTION OF MEAN MONTHLY
WIND SPEED (Jordan, 1973)



Hurricanes release tremendous amounts of energy. A single storm may release 300-400 billion kwh per day. During the same period of time, 10-20 billion tons of water will fall in the form of rain during the average nine day life of a hurricane (Miller, 1971). On the average, 6-12 inches of rain will fall on a given location; although some storms are virtually dry, one tropical cyclone dropped 35 inches of rain in Trenton, Florida in three days in 1941 (Gentry, 1973). Much depends, of course, on the path and characteristics of a particular storm. On the average, they move over the surface at the rate of 12 mph. They tend to be slower below 30 degress North latitude while steered west or northwest by the easterly trades. Once they enter the westerlies, they tend to veer to the northeast and commonly accelerate. Forward speeds up to 50 mph have been reported. As the storm moves over the colder waters of the North Atlantic or over land, less moisture becomes available, the storm loses energy and coherency, and ultimately dissipates.

Because of their large size, their common occurrence, and the enormous amount of energy they release, hurricanes pose a particular danger to all the areas they affect. In coastal areas such as the Keys three primary effects are associated with hurricanes: wind, waves and storm surges.

Wind: Because the dynamic pressure of the wind increases with the square of the wind velocity, tremendous pressures are exerted on vegetation and structures. A hurricane with winds of 75 to 100 mph can generate pressures of 75 lb/sq ft, enough to destroy mobile homes and cottages. As the wind flows around structures, it creates pressure differentials that are sufficient to collapse them. The passage of the intense low pressure center over sealed buildings can have a similar effect (Stursa, 1973).

Waves: Because of the intense winds and the long duration of these storms, they generate large waves commonly 35 feet in height, but reaching up to 50 feet. As these waves reach the shoreline, they erode beaches, highways, undermine structures, and rework sediments. Developed coastal areas where beach berms have been removed and canals that have been cut to the shore are particularly vulnerable to storm wave action.

Storm Surges: Perhaps the greatest danger to low-lying areas such as the Keys is the storm surge that may be associated with any hurricane that approaches or crosses a coast. The storm surge is commonly composed of three elements that reinforce each other. First, as the low pressure center passes over an area, sea level will bulge below the low pressure area by as much as two feet because of the decreased barometric pressure. Second, because the shoreline acts as a barrier, the water is piled up against land by winds. Third, high tides may combine their amplitude with the rise in water from the other factors. In Pass Christian, Mississippi, in 1969, the storm surge reached 25 feet; the highest surge recorded in the Keys reached nearly 18 feet

during the "Labor Day" Hurricane of 1935 (Gentry, 1973; Stursa 1973). While such a rise is extreme, surges in excess of ten feet are not uncommon and, if one visualizes storm waves up to 20 feet in height superimposed on these surges, one can readily understand the potential destructiveness of a large hurricane. Associated with tidal surge flooding and wave pounding are surge currents which are responsible for sediment reworking and transport. Although surges are common phenomena, their amplitude and destructive potential are difficult to predict, depending as they do on a host of factors such as wind speed, direction, fetch, water depth, basin and coastal shape, as well as currents, tides and seiches, to name but a few.

Secondary effects of hurricanes may include damage to vegetation as well as marine biota because of sudden changes in temperature and salinity, as well as direct effect on the aquifer by flooding recharge areas (Stursa, 1973; Craighead and Gilbert, 1962). In extreme cases, entire coastlines have been obliterated. It should be borne in mind, however, that hurricanes are natural parts of ecosystems and water budgets of many areas. With the passing of the years and a better understanding of these severe storms, loss of life has drastically decreased, even though (because of increased development of the coastlines) property damage continues to rise steadily.

The effects of hurricanes on the Keys' natural ecosystems can be devastating. The storm surge and associated wave action especially impact shoreline systems such as salt ponds, beaches, berms and mangrove communities. Hurricane Donna substantially changed shorelines throughout the Upper Keys. Some smaller Keys were practically obliterated, some were severed, and in many areas low dune ridges were stripped of vegetation (Craighead and Gilberg, 1962). The effect of such disturbance is to return these systems to a pioneer seral stage. Craighead and Gilbert (1962) further noted that these forces dispersed Red Mangrove (Rhizophora mangle) seeds several miles inland and certainly represented the source of the extensive inland stands of this species.

The winds of severe hurricanes will directly uproot much of the vegetation in the path of the eye and defoliate most of the remainder. While much defoliated vegetation produces new foliage, some species, especially mangroves, may be characterized by high mortality for reasons that are unclear, although high soil hydrogen sulfide generated by anaerobic decomposition of newly deposited organics may be a major factor (Craighead and Gilbert, 1962).

While mangroves were often decimated by hurricanes, some species of upland vegetation fare much better. Especially wind-resistant species are:

Cabbage Palm	*Sabal palmetto*
Royal Palm	*Roystonea elata*
Live Oak	*Quercus virginiana*
Strangler Fig	*Ficus aurea*
Mastic	*Sideroxylon foetidissimum*
Lysiloma	*Lysiloma bahamensis*
Slash Pine	*Pinus elliottii*

Areas affected by storm surges may be temporarily damaged by the increased salinity of water or soil. If drainage is poor, as in some wetland areas, recovery may take several years (Stursa, 1973), but the torrential rains that accompany hurricanes tend to offset this damage and the region's high annual rainfall tends to leach away deposited salts and promote a faster recovery in most plant communities.

Since hurricanes are recurring natural phenomena, most Keys biota have evolved some degree of accommodation. Consequently, a fairly predictable successional sequence tends to generate anew the destroyed system. One factor that can complicate this recovery, however, is the introduction of propagules of exotic plant species. Many such species, especially Brazilian Pepper (*Schinus terebinthifolius*) and Australian Pine (*Casuarina equisetifolia*) are opportunistic forms that rapidly colonize disturbed sites and may delay or adversely affect ultimate recovery. Further, the latter species is very salt tolerant and tends to suffer less than many native species when exposed to subsequent storm surges (Alexander, 1968).

Another major impact of hurricanes on upland systems is the removal or reduction of the thin humus layer that overlies the limestone. The significance of this humus is discussed elsewhere, but it can be stated here that its diminution sets back the successional sequence to an earlier seral stage in which many environmental variables (temperature, surface moisture) become more extreme.

2.
CORAL REEFS

Coral reefs are among the Earth's most complex and productive natural systems. These shallow water ecosystems rest on a limestone substratum of their own production in stable environmental conditions. The saltwater environment is warm (above 70 degrees F.) and transparent enough to afford access to the intense bright light required by many reef inhabitants.

The structural framework of coral reefs is composed of colonies of tiny organisms collectively called coral. These organisms extract calcium and carbonate ions from seawater to secrete calcareous chambers within which they live. The growth of a coral reef, therefore, represents the collective actions of the many individuals comprising these colonies and is a slow process. This structural framework provides food and/or habitat for a vast number of organisms.

The principal extant reef builders are hermatypic corals (DiSalvo & Odum, 1974) whose symbiosis with unicellular algae called zooxanthellae provides a mechanism for maximizing reef growth. The algal species occur in the endodermal tissue of their host where they are protected by its calcareous skeleton, which is spatially oriented to maximize illumination. This advantage is maximized in associations with the many corals whose polyps are extended out of this structure during daylight hours (Wainwright, 1967). These algae provide their host with oxygen as a metabolic byproduct of photosynthetic activity and organics (Muscatine, 1967).

The coral reefs of the Florida Keys are at the northern edge of the geographic range of these systems. Consequently, their structural organization may differ somewhat from the classic patterns observed in most Caribbean reefs where physical conditions are more constant. Nonetheless, the pattern of Keys reefs approaches the "barrier reef" model originally advanced by Charles Darwin.

The most seaward component of this barrier complex is an outer reef system that develops at the crest of an escarpment (See Figure 8) at the outer edge of the shallow continental shelf that occurs along the Atlantic edge of the Keys. Because of the linear regularity of this geomorphological feature, outer reefs tend to linear systems that parallel the Keys.

Landward of the outer reef lies a shallow lagoon and coral system characterized by less structural regularity of its coral components. These "patch reefs" are of scattered and irregular distribution, shape and size. Differences in the physical environments of the barrier and patch reefs are reflected in the differing morphologies of their dominant coral species. The patch reefs of the lagoon area live in shallow water that is more strongly influenced by wave action that can increase turbidity, and by weather changes that can result in a range of thermal variation unknown in the deeper waters of the outer reef. The evolutionary accommodation to these conditions has been the predominance in patch reefs of massive boulder-shaped corals whose morphology is better able to withstand the high wave energy and concomitant turbidity.

The corals along the outer reef do not experience such stressful conditions. Here the thermal condition is stablized by the influence of warm Gulf Stream waters, and sediments that could contribute to turbidity are instead transported into the ocean's depths by the zone's many sand channels. As a partial consequence, the outer reef is inhabited by many corals with branched and plated morphologies.

Further, there exist discontinuities in Keys barrier reef distribution that reflect geographic discontinuities in the archipelago itself. The chain of islands that comprise the Upper Keys constitute a continuous barrier to the exchange of water

between Florida Bay and the Atlantic. Consequently, the Gulf Stream's thermally moderating influence is more constant here than in the Lower Keys where the archipelago is fragmented and seasonal thermal variations are more profound. Further, these passages in the Lower Keys indirectly allow the generation of turbid water. The consequence of these differences is that major reef development in the lower Keys is limited to the "shadow zone" south of major islands, e.g., the Sambo reefs south of Big Coppitt and Geiger Keys, and Looe Key Reef south of Big Pine Key where environmental conditions are more constant.

Biota

There are over 6,000 patch reefs between Miami and the Marquesas Keys (Schomer & Drew, 1982). Most occur in areas of sand, mud, or rock substrate located in a band two to four miles from the islands between Hawk Channel and the outer reefs (Marszalek, et al., 1977).

There are two basic types of patch reefs (Marszalek, et al., 1977; Jaap, 1982) -- dome patch reefs and linear patch reefs. Dome patch reefs usually occur in clusters in water depths of less than 30 feet and vary in size from a few meters to more than 700 meters (Schomer & Drew, 1982). They are typically circular or eliptical and are surrounded by a halo of barren substrate. The community's biota varies greatly depending on reef age and environmental condition (Jaap, 1982), but typically consists of scleractinian and alcyonarian corals, other coelenterates, mostly erect sponges, echinoderms, crustaceans, molluscs, red and green algae, and a variety of fishes.

Jones (1977) described a successional sequence for dome patch reefs in which the pioneer corals are likely to be Porites porites, Manicinia areolata, and Favia fragum. These forms are replaced by primary reefbuilding corals like the starlet corals (Siderastrea siderea), the brain corals (Diploria labrinthiformis and D. strigosa), the star corals (Montastrea annularis and M. cavernosa), the finger corals (Porites porites and P. furcata), and Colpophyllia natans.

The coral assemblage of linear patch reefs is similar to that of dome patch reefs, but elkhorn coral (Acropora palmata) joins Montastrea annularis as a principal reefbuilder. Linear patch reefs usually occur seaward of dome patch corals and lie roughly in a chain parallel to the outer reefs. Both types of reefs commonly have the algae Gonialithon sp. and Halimeda opuntia, numerous erect sponges, bivalves of the genera Arca, Lithophaga, and Barbatia, the gastropods Strombus gigas and Coralllophils abbreviata, spiny lobsters (Panulirus argus), stone crabs (Menippe mercenaria), the echinoids Diadema antillarium and Echinometra lucunter, numerous ostracods, bryozoans, foraminifera, ostracods, and fishes (Enos, 1977; Multer, 1977; Jaap, 1982). Table 1 lists some of the common fish species of patch reefs.

Outer reefs are located at or near the shallow shelf break. The elongated reefs form a discontinuous belt that is best developed seaward of Key Largo and the Lower Keys. The biota of the outer reefs include Porites astreoides, Lettuce Coral (Agaricia agaricites), Clubbed Finger Coral (Porites porites), Siderastres sidera, Elkhorn Coral (Acropora palmata), Staghorn Coral (A. cervicornis), Pillar Coral (Dendrogyra cylindrus), Gorgonia ventalina, Plexaura complanata, Diploria clivosa, the alcyonarians Plexaura flexuosa, Pterogorgia citrina, and Eunicea mammosa, the hydrozoan Millepora complanata, the green algae Halimeda, the brittle stars Ophiothrix orstedii and Ophocnida sp, and coralline algae. These are a small fraction of the total species assemblage of outer reefs. Kissling (1977) identified from nine outer reefs off the Lower Keys over 350 macrobenthic species, including 42 species of stony corals, 41 species of soft corals, and 21 species of brittle stars. It is further estimated that over 300 fish species inhabit these reefs. Some of the more commonly occurring fish species are listed in Table 1.

Few other vetebrates occur with regularity. Three species of sea turtle may occur with varying frequency in coral reef although all utilize other habitats. These are the Atlantic Ridley (Lepiochelys kempi), Atlantic Green Turtle (Chelonia mydas mydas), and Atlantic Loggerhead (Caretta caretta caretta). Bottle-nosed Dolphins (Tursiops truncatus) occasionally may also be observed in or near reefs, but it is not a princpal habitat for this species. All four of these vertebrates are listed by federal and/or state agencies as threatened/endangered.

Table 1:
COMMON FISH SPECIES OF KEYS' CORAL REEFS

Outer Reef

Creole Wrasse	Clepticus parrai
Blue Chromis	Chromis cyanea
Brown Chromis	Chromis multilineata
Rock Beauty	Holacanthus tricolor
Parrotfish	Scarus spp.
Hogfish	Lachnolaimus maximus
Sargeant Major	Abedefduf saxatilis
Bluehead	Thalassoma bifasciatum
Striped Grunt	Haemulon striatum
Smallmouth Grunt	Haemulon chrysargyreum
Bluestriped Grunt	Haemulon scrius
French Grunt	Haemulon flavolineatum
Spanish Grunt	Haemulon macrostomum
Grey Angelfish	Pomachanthus arcuatus
Grey Snapper	Lutjanus griseus
Glassy Sweeper	Pempheris schombergki
Porkfish	Anisotremus virginicus
Bicolor Damselfish	Pomocentrus partitus
Flamefish	Apogon maculatus
Squirrelfish	Holocentrus ascensionis

Pearly Razorfish	Hemipteronotus novacula
Seminole Goby	Microgobius carri
Slendor Mojarra	Eucinostomus pseudogula
Eyed Flounder	Bothus ocellatus
Ballyhoo	Hemiramphus brasiliensis
Scaled Sardine	Harengula pensacolae
Lane Snapper	Lutjanus synagris
Yellow Stingray	Urolophus jamaicensus
Gag Grouper	Mycteroperca microlepis
Nassau Grouper	Epinephelus striatus
Snowy Grouper	Epinephelus nireatus
Jewfish	Epinephelus itajara
Yellowtail Snapper	Ocyurus chrysurus
Barracuda	Sphyraena barracuda
Spanish Hogfish	Bodianus rufus

Patch Reef

Sergeant Major	Abedefduf saxatilis
Bluehead	Thalassoma bifasciatum
Parrotfish	Scarus spp.
French Angelfish	Pomacanthus paru
Black Grouper	Mycteroperca bonaci
Blue Tang	Acanthurus coeruleus
Bluestriped Grunt	Haemulon sciurus
Black Grouper	Mycteroperca bonaci
Gag Grouper	Mycteroperca microlepis
Nassu Grouper	Epinephelus striatus
Snowy Grouper	Epinephelus nireatus
Jewfish	Epinephelus itajara
Yellowtail Snapper	Ocyurus chrysurus
Barracuda	Sphyraena barracuda
Spanish Hogfish	Bodianus rufus

Disturbances

The great diversity of coral reef biota depends either directly or indirectly on a stable physiochemical environment. Any modification of these conditions can be expected to result in changes in the function and structure of reef ecosystems. Of particular significance are possible modifications of temperature, salinity, light intensity, and sedimentation patterns.

Great mortality of reef biota has been recorded as a result of exposure to high temperatures and to the atmosphere in shallow reef systems during extremely low tides (Mayer, 1914; Glynn, 1968). Similar man-induced reef disturbance has been documented and is attributable to thermal effluents from a power plant in Biscayne Bay that caused coral death as far as 1-1/2 kilometers away (Kaplan, 1982).

Most processes that damage reefs, however, are exacerbated by human development in or modification of the Keys upland or shore habitats. Dredge and fill operations, for example,

generate large amounts of sediments that may reach reefs and kill or damage coral other sedentary animals and plants that are unable to clean their surfaces. Upland development also indirectly generates sediments that can damage reefs, e.g. Kanehoe Bay, Hawaii. Clearing of terrestrial habitats directly exposes soil to the actions of wind and water, whereas an anastomosing network of roots holds soil in place in unaltered habitats. Ultimately, most lost sediment will find its way into nearshore waters. Some inwash from terrestrial areas, especially from Florida Bay, has always occurred naturally, and severe weather can similarly increase siltation regimes, but the location of the Keys' living coral reefs represents an accommodation to these influences that has been reached through geologic time. Changes in the rate of sediment generation and release into offshore waters may upset an equilibrium that will not be reestablished for centuries. It is probable that a more substantial impact of development is that attributable to the loss of nearshore areas that are utilized at some point by organisms commonly associated with reefs. Seagrass communities for example, constitute nursery areas for spiny lobsters and feeding areas for several species of snappers.

An associated problem is the concomitant loss from terrestrial systems of nutrients that promote eutrophication in aquatic systems. This process, which may be exacerbated by nutrient release from septic tanks, promotes "blooms" of microorganisms that can cloud the water and reduce light penetration for days at a time. The potentially devastating effects of such processes have been reported for Hawaiian reef systems (Banner, unpubl. ms.) where there occurred a decimation of reef biota. State and County regulatory legislation now exists to prevent or mitigate some of the aforementioned types of environmental damage.

In addition to such indirect damage caused by modifications in the physical environment, direct damage constitutes a major problem to the Keys' coral reefs. The increased presence of humans in these areas, resulting from tourism and Keys population growth, has impacted these systems in several unfortunate ways. Because coral growth is extremely slow, any direct damage to the reef infrastructure should be viewed as semipermanent. Corals broken by collectors and ship anchors or ship hulls, for instance, are aspects of this problem that have been worsened by the high level of human presence here. The potential for extensive physical damage was realized earlier in 1984 when a commercial vessel became grounded on a Keys reef system. Extensive breakage of the reef structure was caused by both the impact of the vessel's hull and its chain and anchor, as well as those of rescue vessels, during attempts to free it. Selective removal of fish (by spearfishing) and mollusk shells can also produce changes in reef community trophic structure.

Oil spills also adversely affect coral reefs. Laboratory studies have shown that floating oil can disrupt the normal feeding and cleaning activities of corals (Reimer, 1975), and

physical contact for more than a few hours causes tissue death (Bak & Elgershuizen, 1976). The ability of corals to recolonize after disruption is greatly reduced by such exposure (Fishelson, 1973) and coral growth rate is reduced by short-term exposure (Birkeland, et al., 1976). Diaz-Pifferer (1962) noted that corals in oil spill areas showed a "bleached" appearance. In other areas of such coral discoloration, the cause has been found to be the loss of the symbiotic zooxanthellae that are so critical to coral metabolism and growth.

3.
THE SEAGRASS ECOSYSTEM

The seagrass community is a highly productive, faunally rich system that covers a larger area than any other ecosystem in Monroe County. Seagrass "meadows" provide abundant food and shelter for a myriad species of fish, sea turtles, and invertebrates and thus probably represent the richest nursery and feeding grounds in South Florida's coastal waterways. Because many commercially important species depend on this system at some point during their life cycle, the continued health of seagrass meadows is critical to the long-term economic wellbeing of the Monroe County community.

While mangroves and coral reefs rarely abut, vast seagrass beds freely intermingle with both systems and bridge the areas between these divergent systems. As transitional habitats, they are important to many species of both ecosystems, either seasonally (as a nursery area) or for regular nocturnal feeding (as in snappers and grunts). In addition to representing a primary resource for grazers, seagrasses provide vast amounts of energy via detritus that may cycle internally or be exported to mangrove or coral reef communities.

Seagrass meadows also are important in stabilizing sediments that would otherwise exist as shifting sand and mud. As such, they represent a critical element in preventing or at least retarding the loss of continental materials that would otherwise be lost by erosion to the ocean's depth.

To appreciate fully the functional importance of seagrass communities one must recognize the huge extent of their geographical range in southern Florida. Of the 10,000 sq. km. (3,860 mi^2) of seagrass in the Gulf of Mexico, over 8,500 sq. km. (3,280 mi^2) are in Florida waters, primarily in Monroe County (Zieman, 1982). Seagrasses cover over 80% of the sea floor in an area bounded by Cape Sable, north Biscayne Bay and the Dry Tortugas, an area of over 5,500 Km^2 (2,120 Mi^2; Zieman, 1982). In an inventory of the estuaries of Florida's Gulf Coast, McNulty et al., (1972) estimated that almost half of the region of Florida Bay west of the Keys and landward to the freshwater line at Cape Sable had submerged vegetation. By comparison, less than 7% of the area was vegetated by mangroves.

Biota

Worldwide, there are approximately 45 species of seagrasses. In Monroe County, there are six species representing 4 genera and 2 families (See Table 1). While these comprise a small percentage of the hundreds of plant and animal species found in seagrass communities, they are clearly the most important forms because the other inhabitants depend, in some way, upon their presence.

Turtle grass (Thalassia testudinum) is the most robust and widespread of the seagrasses, forming extensive meadows throughout its range. Manatee grass (Syringodium filiforme) is more surficially rooted than turtle grass and rarely forms extensive meadows, occurring most commonly mixed with other species or in small dense monospecific patches. Shoal grass (Halodule wrightii) is found primarily in disturbed areas that are devoid of turtle grass or manatee grass and is an important early colonizer of such sites. Overall, it is the most eurycious of the principal seagrass species in that it thrives in waters too shallow or too deep for the other species and is the most tolerant of all species to variations in temperature and salinity (Zieman, 1982). The three species of Halophila are small forms that are sparsely distributed in seagrass communities, seldom comprising an important trophic component.

All other plant species of seagrass communities are of considerably less trophic consequence. Only a few types of algae are capable of colonizing the bottom sediments, notably members of the genera Halimeda, Penicillus, Caulerpa, Rhipocephalus, and Udotea. Still other species of algae attach directly to the leaves of seagrasses.

Table 1:
SEAGRASSES OF MONROE COUNTY (Zieman, 1982)

Family and Species	Common Name
Hydrocharitaceae	
Thalassia testudinum	Turtle Grass
Halophila decipiens	
Halophila engelmanni	
Halophila johnsonii	
Potamogtonacea	
Syringodium filiforme	Manatee Grass
Halodule wrightii	Shoal Grass

The successional sequence which generates a seagrass climax has been documented in "blowout" areas (Zieman, 1982). These denuded blowout areas may originate as a result of a sea

urchin overgrazing, a large anchor dragging, or a major storm. The initial scar is enlarged by water flow into a bare crescentic surface up to 10 meters wide. Pioneer colonizers of this unconsolidated surface are rhizophytic algae, especially species of Halimeda and Penicillus. Because their sediment-binding capacity is limited to their rhizoidal base, they never affect an area greater than a few centimeters away, but instead produce small consolidated sediment balls (Williams, 1981). After this initial sediment consolidation, a succession of seagrasses colonize the blowout surface. The first is shoal grass. In some sequences, manatee grass will next appear and may be mixed with shoal grass at one edge and turtle grass (from an undisturbed colony) at the other. However, manatee grass is the least constant member of this assemblage and is frequently absent altogether. Thereafter, turtle grass colonizes the area and the climax is restored. The time required for recovery will vary depending on the size of the disturbance, wave intensity, and other factors, but in Barbados, blowout restabilization is reported to have taken 5 to 15 years (Patriquin, 1975).

A large invertebrate fauna inhabits seagrass ecosystems. Conspicuous among epibenthic forms are the Queen Conch (Strombus gigas), the Spiny Lobster (Panulirus argus), the Bahamian Starfish (Oreaster reticulata), and numerous sea urchins, most notably Lytechinus variegatus and Tripneustes ventricosus. Numerous epiphytic invertebrates glean a livelihood from seagrass areas by preying on the algae that grow on the leaves of seagrasses. Principal among these are a variety of gastropods (notably Cerithium mascarum, C. eburnum, Anachis sp., Astrea spp., Modulus modulus, Mitrella lunata and Bittium varium) and small crustaceans (especially Cymadusa coompta, Gammarus mucronatus, Melita nitida, Grandidierella bonnieroides, Palaemonetes pugio, P. vulgasis, P. intemedius, and Periclimenes longicaudus). Many invertebrates, including the Pink Shrimp (Penaeus duorarum) and the Spiny Lobster, use seagrass meadows for nurseries.

Diverse and abundant fish faunas also inhabitat seagrass communities. While few, if any, of the many permanent residents are of direct commercial value, these seagrass ecosystems are important nurseries and feeding areas for such species. These include the Sea Bream (Archosargus rhomboides), the Sheepshead (A. probatocephalus), the Gag Grouper (Mycteroperca microlepis), the Redfish (Scriaerops oscellata), the Gray Snapper (Lutjanus griseus), the Lane Snapper (L. synagris), the Dog Snapper (L. jocu), the Mutton Snapper (L. annalis), the Yellowtail Snapper (Ocyurus chrysurus), and the Spotted Seatrout (Cynosciov nebulosus). Other fish that extensively utilize seagrasses as nursery areas are:

Pinfish, Lagodon rhomboides
Spot, Leiostomus xanthurus
Silver Perch, Bairdiella chrysura
Pigfish, Orthopristi chrysoptera
White Grunt, Haemulon plumeri

Ocean Sturgeon, Acanthurus bahianus
Doctorfish, Acanthurus chirurgus
Spotted Goatfish, Pseudupeneus maculatus
Yellow Goatfish, Mulloidicthys martinicus
Bucktooth Parrotfish, Sparisoma radians
Redtail Parrotfish, S. chrysopterum
Stoplight Parrotfish, S. viride
Redfin Parrotfish, S. rubripine
Striped Parrotfish, Scarus croicensis
Rainbow Parrotfish, S. guacamaia
Midnight Parrotfish, S. coeruleus
Emerald Parrotfish, Nicholsina usta

Several sportfishing species, most notably the Tarpon (Megalops atlanticus), Bonefish (Albula vulpes) and Permit (Trachinotus falcatus), depend upon seagrass systems.

In areas where seagrass meadows abut coral reefs, many prominent species of reef fish move into seagrass areas to feed at night. Principal among them are members of the families Pomadasyidae, Lutjanidae, and Holocentridae.

The only reptile for which seagrass constitutes a principal feeding habitat is the Green Sea Turtle (Chelonia mydas). Human predation has reduced Chelonia populations to a level estimated by Zieman (1982) to be between .1% and 1% of their pre-Columbian abundance and has brought them to the verge of extinction. Presently, it is classified as a federal endangered species. Thus it is important that all habitat critical to their survival, including seagrass meadows, be afforded protection from degradation.

Large numbers of birds are known to feed extensively in shallow seagrass meadows including the threatened (Federal Status) Brown Pelican, Pelecanus occidentalis. These are listed in Table 2.

Two aquatic mammals known to commonly use seagrass communities are the Caribbean Manatee (Trichechus manatus) and the Bottlenose Dolphin (Tursiops truncatus). While Bottlenose Dolphins are common in South Florida waters generally, they are not especially common in shallow seagrass meadows (such as in Florida Bay) because the extreme shallowness precludes extensive utilization by such a large mammal. Caribbean Manatees are an exceedingly rare form whose low total population has resulted in their designation as an endangered species. Formerly the range of the Caribbean Manatee was considerably greater, but the population now seems to be centered around the protected regions of Everglades National Park. A survey of the Everglades' Caribbean Manatee population by Odell (1976) found a total of 772 individuals; 46% were sighted in Whitewater Bay, 20% in the Gulf of Mexico, 23% in inland waters, and only 1% in Florida Bay. A later study (Odell, 1979) reported no sightings in Biscayne Bay. There are, however, documented sightings of Manatees in Florida Bay and several Florida Keys Canals.

Table 2:
BIRDS THAT USE SEAGRASS FLATS IN FLORIDA KEYS

(Prepared by Alexander Sprunt, IV)

Common Name	Species Name	Preferred Feeding Tide
WADERS:		
Great Blue Heron	Ardea herodias	Low
Great White Heron	A. herodias occidentalis	Low
Great Egret	Casmerodius albus	Low
Snowy Egret	Egretta thula	Low
Little Blue Heron	E. caierulea	Low
Tricolored Heron	E. tricolor	Low
Reddish Egret	Egretta rufescens	Low
White Ibis	Eudocimus albus	Low
Roseate Spoonbill	Ajaia ajaja	Low
Black-bellied Plover	Pluvialis squatarola	Low
Wilson's Plover	Charadrius wilsonia	Low
Semipalmated Plover	C. semipalmatus	Low
Willet	Catoptrophorus semipalmatus	Low
Ruddy Turnstone	Arenaria interpres	Low
Red Knot	Calidris canutus	Low
Western Sandpiper	C. mauri	Low
Least Sandpiper	C. minutilla	Low
Dunlin	C. alpina	Low
Short-billed Dowticher	Limnodromus griseus	Low
SWIMMERS:		
Horned Grebe (winter only)	Podiceps auritus	High
American White Pelican (winter only)	Pelecanus erythrorhynchos	High
Double-crested Cormorant	Phalacrocorax auritus	High
Red-breasted Merganser	Mergus serrator	High
FLYING PLUNGERS:		
Brown Pelican	Pelecanus occidentalis	High
Osprey	Pandion haliaetus	High
Bald Eagle	Haliaeetus leucocephalus	High
Laughing Gull	Larus atricilla	High
Ring-billed Gull (winter only)	L. delawarensis	High
Herring Gull (winter only)	L. argentatus	High
Royal Tern	Sterna maxima	High
Forster's Tern (winter only)	S. forsteri	High
Least tern (summer only)	S. antillarum	High

Disturbances

The principal naturally occurring damage to seagrass communities results as a consequence of the intense wave action brought by hurricanes. As was discussed previously, the successional colonization of the resulting "blowouts" may require a decade or more.

The greatest amount of direct damage to seagrass communities has come as a result of dredge-and-fill operations. Filled areas, of course, become the sites of developed features and cease to function as natural systems; dredged areas are equally severely damaged, primarily by the change in sediment characteristics making them unsuitable for seagrass recolonization for long periods (Zieman, 1975). The indirect adverse effects of such activities include increased turbidity and depletion of dissolved oxygen. The former reduces light penetration, thereby restricting productivity of surrounding systems and congesting the feeding apparatus of filter feeding animals. Oxygen depletion, a consequence of the oxidation of suspended organic materials, makes the system less hospitable to aerobic organisms. Because dredged sediments are unconsolidated and easily suspended, the banks of fill areas can be source areas for turbidity for long periods. The ultimate ecological consequence of such activities is the destabilization and impoverishment of the affected ecosystems and significant economic loss for fisheries and recreation industries (Taylor and Saloman, 1968).

Zieman (1975) considers cuts from boat propellers to be the most common type of disturbance of South Florida's seagrass beds. He suggests that recovery from a single prop cut begins in about 2 years and takes at least 5 years for completion. Multiple cuts in grass beds frequented by boaters may persist for a decade or more.

Eutrophication of seagrass communities may occur through the addition of nutrients from sewage, industrial wastes or erosional runoff. The profusion of algal growth fostered by such enrichment increases turbidity and thereby reduces the photosynthetic efficiency of seagrasses. Further, the increased deposition of dead organic matter (algae, seagrass leaves) reduces the concentration of dissolved oxygen on the sea floor and thereby adversely affects the seagrass rhizomes. In some cases (Taylor et al., 1973; McNulty, 1970), seagrass populations are severely reduced or eliminated by these processes.

Other documented declines in seagrass populations have been caused by oil spills (Zieman, 1982) and thermal pollution from power generating facilities (Zieman and Wood, 1975). Further, structures built over seagrass beds will shade out the vegetation of an area roughly proportional to the size of the structure.

4.
MANGROVES

Mangroves and the mangrove community have long been of special interest to naturalists and scientists. Literature on mangroves dates back to Theophrastus (305 B.C.), Plutarch (A.D. 70), Pliny (A.D. 77), and Arrian (A.D. 136). A significant body of literature, describing mangroves throughout the world, has accumulated since this early period. Recent research has involved efforts by numerous scientists in disciplines ranging from ecology and biogeography to molecular biology and microbiology. Comprehensive reviews of this work have been published by Lugo and Snedaker (1974) and by Odum et al., (1982).

Much of the recent research has been directed towards determining the functional role of the mangrove community in marine ecosystems. This effort, in part, is a response to development pressures that have resulted in the elimination or degradation of many thousands of acres of Florida's wetlands. Consequently, a large and accessible data base is now available for use in land planning and resource management decisions.

Biota

The "mangrove community" is composed of a diverse association of salt tolerant plants that provide food and habitat for a characteristic fauna. The major environmental conditions that characterize this system are:

1. Loose, wet, saline soils.
2. Periodic tidal submergence.
3. Occasional tropical storms and/or hurricanes.
4. Low-energy wave and current regimes.

The dominants of this association are the mangroves of which, in South Florida, there are three species. Red Mangrove (Rhizophora mangle) has characterisitc stilt, prop and aerial roots and bears the cigar-shaped, viviparous seedlings. Black Mangrove (Avicennia germinans) has "pneumatophore" breathing roots and gray-green leaves encrusted with excreted salts. White Mangrove (Laguncularia racemosa) has rounded leaves with a pair of salt glands on the petiole. Buttonwood (Conocarpus erectus) is often associated with the mangroves but is not a dominant. It occurs more frequently in what is termed the "transitional zone" that lies on slightly higher ground between the mangroves and upland systems. Other plants commonly associated with the mangroves include a number of fleshy halophytes, e.g. Saltwort (Batis maritima), Glasswort (Salicornia virginica), etc.

In Florida, the Black Mangrove enjoys the most widespread distribution, ranging from St. John's County on the east

coast and along the entire Gulf coast. Red and White Mangroves are less widely distributed; they range from Cedar Key on the west coast to north of the Ponce de Leon Inlet (Volusia County) on the east coast. The distributional range of Buttonwood is similar to that of the White and Red Mangroves. At the limit of their respective ranges, these plants do not form the dense associations that are typical of the South Florida populations, but occur as scattered small trees. In some areas the mangrove association is replaced by Juncus or Spartina marshes.

According to Odum et al. (1982), the four major factors that limit the distribution of mangroves and determine the extent of mangrove ecosystem development are 1) climate, 2) salt water 3) tidal fluctuation and 4) substrate. Odum cites work which shows that mangroves do not develop where the annual average temperature is below 66 degrees F or where water temperatures exceed the 107-113 degree F range. Contrary to popular belief, mangroves do not require salt water but are "facultative halophytes", i.e. they do not develop in freshwater environments only because they are not able to compete successfully with other plants in that environment.

Although tidal flow is not essential for mangroves, it benefits them by carrying nutrients into the system, preventing excessive salt loading of soils and dispersing their propagules. According to both Odum et al. (1982) and Davis (1940), mangroves grow best in depositional environments with low wave energy because high wave energies prevent establishment of propagules, stress the root system and prevent accumulation of fine sediments. Wrack accumulations also tend to smother propagules and prevent their establishment.

The historically accepted pattern of mangrove zonation was initially described by Davis (1940). The seaward zone of the intertidal area is dominated by Red Mangroves occurring as a pure stand. Moving landward, Black and White Mangroves mix with the Reds in varying proportions and, on the higher ground, Buttonwood increases in frequency. This zonation scheme was also accepted as the successional sequence leading to the climax forest, the tropical hardwood hammock, with each zone equivalent to a seral stage. More recently, some ecologists (Odum et al., 1982; Ball, 1980) have disputed this hypothesis and suggest that these zonation patterns appear to result from the differential influence of physical factors on the competitive abilities of the mangrove species.

Lugo and Snedaker (1974) have classified mangrove systems into six types based upon their physical structure. The five that occur in the Florida Keys are overwash forest, fringe forest, riverine forest, basin forest, and scrub or dwarf forest.

Overwash forests are found on small keys or peninsulas. In many cases overwash forest is the only community on a small island. These forests are regularly overwashed by tides

and often contain no land that rises above mean high water. All three mangrove species may be present, but Red Mangroves are usually the dominant form, with canopy height ranging from 20 to 25 feet. Because of the regular tide sheet overflow, litter does not accumulate and organic export rates are high. These are the preferred roosting and nesting areas for a number of birds, since they are isolated from most predators, e.g. rats, raccoons and feral cats.

Along low-energy shorelines mangroves form fringe forests of variable width and canopy height ranging from 20-30 feet. The zonation pattern of fringe forests closely approximate the classic scheme. Low tide and current velocities allow for colonization by these trees and for the import and subsequent accumulation of sediments. The prop roots of Red Mangrove and the pneumatophores of Black Mangrove are particularly effective in sediment accumulation. Fringing forests that face open bodies of water to the north accumulate vast amounts of detritus, much of which is generated by the productive nearshore seagrass communities. The organic sediments that accumulate within the fringe forest are often strongly anaerobic. In these soils, Black Mangroves tend to dominate, probably because their pneumatophores ("air roots") allow access by underground portions of the tree to atmospheric gases. These root systems enable mangroves to withstand the wind and wave energies of tropical storms and provide substrate for marine algae and invertebrates and a sanctuary for small fish. In fringe forests, populations of succulent, salt tolerant plants often form a dense ground cover, the two most common of these are Saltwort and Glasswort. Here, the soil is elevated above mean sea level so that these plants are wetted only by high tides. The soils are often a mixture of organic sediments and coarse, calcareous sand. The trees are usually medium to large and widely spaced; there is no mid-story . The dense association of low-growing succulents, in combination with pneumatophores of the Black Mangroves, acts to entrap sediments and litter, thus increasing the elevation and lessening the influence of the tide. Through this process one can project the future succession to an upland seral stage. This association has recently been recognized as habitat for the endangered (Florida) Silver Rice Rat (Oryzomys argentatus).

The best developed riverine mangrove forests occur along creeks and rivers on the mainland. In the Keys, this forest occurs only along tidal creeks. All three species of mangroves may occur, but the dominant form is usually Red Mangrove. On the mainland, this forest contains the largest trees of all the forest types, with canopy heights in excess of 60 feet; however in the Keys, the structure is similar to that of the fringe forest. High rates of productivity and nutrient export are attributable to the daily tidal flushing. Mangroves growing along tidal creeks are well protected from storms and other external influences.

Basin forests also are not well represented in the Keys, except on Key Largo. In south peninsular Florida, these forests occur inland along drainage depressions where upland runoff is channeled toward the coast. In the Keys, they are found where large shallow depressions in the caprock foster the accumulation of soil and channelize tidal flow. Basin forest structure is similar to overwash forests, but the Red Mangrove does not dominate the system to the same extent. The occurrence of Black and White Mangroves becomes more frequent with increasing soil elevation and diminishing tidal influence.

Scrub or dwarf forest are best developed in the Lower Keys. These communities lack the canopy height and high productivity characteristic of the other forest types. Both the scrub and dwarf (known locally as "spider" mangroves) associations are characterized by small trees with an understory of scattered, salt tolerant shrubs, herbs and graminoids. The scrub community generally contains all three species of mangrove but is usually dominated by Black. Here, the trees are widely spaced and often appear stunted. Dwarf mangrove associations contain trees less than five feet in height, with less distance between trees than in scrub forests. These small trees, usually Red Mangroves, are not juveniles but rather dwarfed forms of this species. Both the scrub and dwarf forests occur in intertidal areas that do not enjoy daily tidal flushing. The minimal flushing may be attributable to natural waterward impediments to flow or to a great spatial separation from open water that alternates tidal flow. Dwarf red mangroves appear to occur on slightly lower elevations than scrub black mangroves.

In many areas of the Lower Keys where the scrub and dwarf forests occur, e.g. Sugarloaf, Saddlebunch, and Torch Keys, the oolitic caprock is emergent, providing limited opportunity for soil accumulation. Where soils do occur, they are characteristically thin, saline marls within shallow caprock depressions. Due to lack of regular tidal flushing, soils often become hypersaline during the dry season and dilute during the wet season. Moreover, propagules are less likely to reach these areas since they are dispersed by the tides. All of these factors make it difficult for mangroves to colonize and survive in these areas. Also, a number of researchers believe that the scrub and dwarf forests may be nutrient limited.

In some rocky intertidal areas conditions are so severe as to preclude the growth of woody plants such as mangroves. Where soils are thin and hypersaline and tidal impacts minimal, salt marshes or salt flats represent the dominant community. These associations are vegetated by salt tolerant graminoids, shrubs and fleshy succulents. There is usually a mangrove fringe forest waterward of the marsh.

In striking contrast to the scrub and dwarf forests, there occur, within these infrequently flooded areas, occasional small strands of very large Black Mangroves. These isolated

pockets are reminiscent of cypress domes or bay heads in the Big Cypress Swamp and Everglades. These trees appear to flourish because they are growing within deep solution depressions in the caprock. These limestone solution formations accumulate substantial amounts of organic soil or peat and are thus able to retain moisture throughout the year. Although they receive tidal input with the same frequency as the adjacent scrub community, the special soil conditions support much higher levels of productivity and tree growth. The fact that these stands are dominated by Black Mangroves may be indicative of anaerobic and saline soil. Similar, although smaller, solution formations in this zone support stands of Red Mangrove larger than those scrub forms on the adjacent higher grounds. These shallow depressions also accumulate organic soils and thus retain soil moisture better than the thin, marl soils that cover the caprock of the scrub zone.

The importance of mangrove systems both to humans and to other natural communities cannot be underestimated. Although the research that has documented this has been, for the most part, conducted outside the Florida Keys, it would certainly be reasonable to extrapolate some of these studies to mangrove systems of this area. Mangroves protect shorelines from erosional damage by tropical storms and hurricanes. This not only protects upland systems but also human communities. Riverine, fringing and overwash forests act as "nursery areas" for a variety of finfish and invertebrates. Many of these are of economic importance to the commercial and sport fishing industries of the Keys as well as to the tourist economy. The commercial species that use mangroves include shrimp, lobster, and various finfish such as snappers. These forests provide both food and sanctuary for larvae and juveniles. Mangroves accelerate the deposition and stabilization of particulate sediments, thereby maintaining water clarity in adjacent open waters and enhancing the ability of marine filter-feeding organisms to obtain food by lowering the energy output required to filter out inedible particulates. Marine seagrasses and algae can photosynthesize more efficiently in clear water and snorkelers and divers enjoy a better recreational experience.

A number of food webs are based on primary production of the mangroves and their associated epiflora. Energy flows stemming from mangrove-derived carbon begin their movement through these food webs as detritus, dissolved organize compounds, or as the products of direct grazing. Other pathways involve bacteria, fungi, macroalgae and phytoplankton associated with mangroves. This energy is often transferred to the human community by the sport and commercial fishing industries.

Certain mangrove communities also provide feeding, nesting and roosting habitat for numerous wading and fish birds. Not only is the intrinsic value of this avifauna inestimable, but as a wildlife attraction, it augments tourism. Odum et al. (1982) provides a list of 181 species of birds that use mangroves in south Florida. Among these, the following species are a major component of the avifauna of the Keys:

Great Egret	Casmerodius albus
Snowy Egret	Egretta thula
Great White Heron	Ardea herodias occidentalis
Great Blue Heron	Ardea herodias
Reddish Egret	Dichromanassa rufescens
Tricolored Heron	Hydranassa tricolor
Little Blue Heron	Florida carulea
Green Heron	Butorides striatus
Black-crowned night heron	Nycticorax nycticorax
Yellow-crowned night heron	Nyctanassa violcea
White ibis	Eudocimus albus
Roseate spoonbill	Ajaia ajaja
Double-crested cormorant	Phalacrocorax auritus
Magnificent frigatebird	Fregata magnificens
Osprey	Paudion haliaetus
Mangrove Cuckoo	Coccyzus minor
Kingbirds	Tyrannus spp.
Black-whiskered vireo	Vireo altiloquus
Warblers	Dendroica spp.

All of these species nest in mangroves, usually on overwash islands.

Further, mangrove forests accumulate various nutrients and pollutants derived from upland or oceanic sources. Nutrients are converted to plant biomass and exported in particulate or dissolved form. An undetermined portion may be tied up in the sediments or within the living community. Thus, mangrove systems act as natural filters, cycling some nutrients through the environment and storing others.

Keys vertebrates with endangered and threatened status that use mangroves include:

Caribbean Manatee	Trichechus manatus latirostris
American Crocodile	Crocodylus acutus
Mangrove Terrapin	Malaclemys terrapin rhizophorarum
Key Deer	Odocoileus virginianus clavium
Silver Rice Rat	Oryzomys argentatus
Keys Raccoon	Procyon lotor auspicatus
White Crowned Pigeon	Columba leucocephala
Brown Pelican	Pelicanus occidentalis carolinenis
Bald Eagle	Haliaetus leucocephalus

Disturbances

Adverse human impacts upon mangrove systems in the Keys have been widespread and varied. Since the period of early colonization of the archipelago by European settlers, mangrove areas have been perceived as pestilential, mosquito-breeding swamps that constitute a barrier to settlement. Moreover, fringing

mangrove forests are located on those portions of the Keys that are most valuable as homesites--open, breezy, waterfront locations. Thus, the history of development in the Keys has been one of dredge and fill in mangrove areas. In 1974, the Coastal Coordinating Council estimated that 6,500 acres in the Keys had been dredged or filled. While this figure represents such impact for all Keys habitats, there is little doubt that a high percentage of this acreage was originally mangrove systems. These activities clear waterfront lots and provide navigational access via dredged channels. The fill is used to elevate lots above tidal influence and to create access roads. These activities totally destroy mangrove forests.

The construction of roads in and adjacent to mangrove areas has both direct and indirect impacts upon the coastal ecosystem. Clearing and filling of roadways devastates the on-site community while impoundment may isolate wetlands from tidal sheet flow, drastically altering the physico-chemical character of their environment. Salinity regimes change, nutrient exchange is blocked, export of organics is prevented, and fish and invertebrates lose their avenues of access to the sea. The long-term results of impoundment include: 1) loss of biotic diversity; 2) diminished productivity; 3) loss of wildlife habitat; and 4) diminished secondary productivity of nearshore marine systems. Where roads do not totally impound wetlands, these adverse impacts do not occur until a storm washes large quantities of seawater into the impoundment and man-made constraints on flushing prevent its release back to sea. Subsequent evaporation of the freshwater component leaves the impoundment with a hypersaline condition that results in high mortality for some populations.

Hurricanes have the greatest impact of any natural force on all of the Keys' terrestrial communities. Severe storms may completely destroy a mangrove community and, in some cases, (Craighead, 1971), the subsequent successional sequence may generate a different community type.

The effects of human settlement within and adjacent to mangrove areas is most profound on wildlife populations. Birds, such as White-crowned Pigeons, are easiliy disturbed by human activity and will not nest near urbanized areas. Secondary impacts include predation on wildlife, such as lizards and birds, by domestic animals (i.e. cats and chickens), molestation of wildlife by dogs, attraction of edificarian species, such as Black and Norway Rats (which feed on nesting birds), and introduction of exotic plants, such as Brazilian Pepper.

Trimming of mangroves to increase breeze, improve views, or eliminate mosquitos is a common practice in the Keys. This diminishes primary productivity, eliminates bird habitat and changes air flows in the immediate upland natural community. This last effect may negatively impact hardwood hammocks by allowing salt spray and drying winds into a forest that is very sensitive to moisture and salt.

5.
TRANSITIONAL HABITATS

In the Florida Keys, the "zone of transition" is that area that generally lies landward of the mangrove fringe and seaward of an upland community not normally influenced by tides. Within this zone, two basic types of communities are recognized: the salt marshes are lower transitional wetlands and the Buttonwood (Conocarpus erectus) associations are generally higher transitional wetland communities. Transitional wetland communities include all tidaly influenced wetlands that are not dominated by large, fringing mangroves or areas of "spider mangroves". The transitional buttonwood zone is the community between the salt marsh zones and the higher upland habitats such as hammocks and pinelands which are not influenced by tides, not dominated by large fringing mangroves or areas of "spider mangroves".

In transitional habitats several of the most important environmental factors that control species distribution occur along a gradient, or "cline". These are functions of tidal influence and are linearly related to distance from mean high water. They include a) duration of submergence, b) duration of exposure, and c) frequency of submergence. Thus, the position of an individual plant or invertebrate population within the transitional zone reflects an adaptive response to this complex of environmental gradients. In the case of animal populations, the availability of food and cover also influence distribution.

The Florida Keys experience mixed, semidiurnal tides of low amplitude (3 feet), with two unequal high and low tides each tidal day. Because of this low amplitude, the inundation of the transition zone may be affected by several other factors including wind direction and velocity, shoreline exposure, and slope. Microrelief is another determinant of vegetation patterns in the transitional zone since areas of exposed caprock do not accumulate soils as do shallow, eroded depressions. These depressions may be acres in extent or only large enough to support a single plant. Elevation of the substrate, and thus drainage patterns, may also affect large or very small areas. The resulting vegetation pattern in Keys' transitional zone is a "mosaic" of plant populations.

Biota

Organisms living in the seaward portion of the transition zone are subject to tidal inundation more frequently and of longer duration than those higher upslope. A species' response to the ratio of submergence/exposure and the salinity regime of its habitat may be morphological, physiological or, in the case of animal populations, behavioral. Some plants, for example, have glands which excrete the salts that enter through the roots, whereas others become succulent, thereby diluting the salts.

Saltgrass (Distichlis spicata), an exceptionally widespread component of coastal marshes, is extremely salt tolerant and has a fast-growing rhizome system that promotes colonization and allows it to respond rapidly to substrate changes. Crustaceans, such as fiddler crabs (Uca sp.) and molluscs, such as the peanut snail (Cerion sp.), move vertically with the tide.

Tidal marshes are among the world's most productive ecosystems. Although no studies of marsh productivity have been carried out for the Florida Keys, southern marshes generally are known to produce annually up to ten tons of marsh grass per acre, whereas northeastern U.S. marshes produce biomass in the range of 3 to 7 tons (Niering and Warren, in Clark, 1977). Much of this plant production becomes available as organic detritus that provides the chief food base for the coastal fish and shell-fish populations of commercial importance. Further, coastal marshes provide food, shelter and nesting sites for numerous species of waterfowl and wading birds, as well as habitat for a variety of small mammals and reptiles. Marshes act as nutrient traps and pollution filters thereby maintaining high water quality in nearshore waters. These systems also slow down runoff and trap particulates which would otherwise reduce nearshore water clarity and create stress for both marine filter feeders and large predators.

The transitional habitats of the Keys, by definition, contain species representative of both adjacent plant communities. Salt marshes and Buttonwood scrub forests are distinguished from adjacent mangrove and upland hammock associations because the "dominant" elements differ in terms of "frequency of occurrence" and/or coverage. Although Buttonwood occurs quite often in both mangrove and low hammocks, it is not the dominant element. Buttonwood, especially the larger trees, occurs on ground that is slightly higher than that of the fringing mangrove community. Buttonwood scrub usually occurs as an open stand with an understory of salt tolerant succulents and small shrubs, e.g. Saltwort (Batis maritima), Sea Daisy (Borrichia frutescens) and Dropseed (Sporobolus virginicus). Upland, the Buttonwood association grades into low hammock, where it also occurs with some frequency but is not dominant. Olmstead, et al. (1981) point out that in the coastal area of Everglades National Park, between Flamingo and Joe Bay, Buttonwood stands and hammocks intergrade and become difficult to distinguish from each other.

Salt marshes, distinguished from adjacent associations by their low stature and lack of woody vegetation, are dominated by salt-tolerant herbs, shrubs and grasses. Howard's (1950) description of the "salicornia tidal flats" of Bimini closely approximates that of Keys' salt marshes. These marshes are often found in association with areas of bare ground known as "barrens" that are devoid of macrophytic vegetation and commonly contain only mats of periphyton. Davis (1940) believes that these zones of virtually bare ground are shallow depressions in the substrate wherein high salinities (80 ppt) eliminate plant life. There is

little question that Keys' salt marshes are a transitional community wherein soils display highly variable levels of salinity.

The type of transitional association that develops in the Keys is a result of the primary interaction between tide and topography. In the middle and upper Keys, there is a relatively steep slope to the high ground, which is elevated above normal tidal influence. In these areas, a hammock is often found within a short distance from the high water mark. On the Florida Bay side of Vaca and Fat Deer Keys, for instance, there is a narrow, rocky, intertidal zone with scattered mangrove, Buttonwood, herbs and grasses that grades into a zone of small shrubs and trees that tolerate sea spray. This "thorn scrub," or "low hammock," protects the upland hammock. On the ocean side of Key Largo, the slope of the intertidal zone is not as great, and one finds a wider zone of transitional salt-tolerant vegetation landward of the mangroves.

In the lower Keys, where the slope of the intertidal zone is very slight, one finds the broadest expanse of transitional zones. On Sugarloaf, Cudjoe, Big Torch, Little Torch, and on a number of other islands, transitional zones occupy areas hundreds of feet in width. On these keys, much of the eroded, oolitic caprock is exposed, creating a "karst-like" substrate with disjunct, shallow depressions containing marl soils. Most of these areas are wetted only by the highest normal tides and by storm tides.

In the most seaward subzone of these broad, rocky transitional areas one usually finds "scrub mangrove" communities dominated by small Red and Black Mangroves with an understory of Glasswort (Salicornia spp.), Salt Grass (Distichilis spicata), Key Grass (Monanthochloe littoralis) and Sea Daisy (Borrichia frutescens). Moving upland, there is a change to a more diverse plant community with fewer mangroves. Depending on drainage and soil conditions, this association can be either Buttonwood scrub or salt marsh.

Some salt marshes are mixtures of fleshy halophytes, including glasswort (Salicornia virginica and S. bigelowii), Purslane (Sesuvium portulacastrum) and Saltwort with occasional Sea Daisy and small mangrove. Other marshes are dominated by grasses, including Salt Grass, Key Grass, and Dropseed, and occasional Fimbristylis castanea, Sea Daisy, Saltwort, Buttonwood and small mangrove. These graminoids and herbs occur as small, disjunct populations forming a mosaic. In some cases a single population will occupy an area of about a half acre, whereas in others, the same species might be represented by only a few individuals. This distributional variability probably reflects the area's microrelief, which determines drainage and soil salinity.

On the slightly higher ground of Sugarloaf, Big Pine, Water, Crab, and several other keys, pure stands of Chestnut Sedge or Cordgrass occur. These areas are somewhat reminiscent

of the marshes of the middle Atlantic coast, but on a much smaller scale.

The most landward subzone generally contains the most diverse flora because of its proximity to rich upland hammocks. Here, Buttonwood becomes abundant and is generally associated with an understory of Sea Daisy, Dropseed, Sea Oxeye (Borrichia arborescens), Cordgrass, Chestnut Sedge, Christmas Berry (Lycium carolinanum) and other small shrubs, herbs and graminoids. The open aspect of this association, resulting from the branching habit of the Buttonwoods, allows much sunlight to reach the ground and generates abundant vegetation beneath these trees in areas with adequate soil accumulation. A frequent epiphyte on these trees is the bromeliad Tillandsia circinata, a species that requires high exposure and is very resistant to desiccation. The Wild Allamanda (Urechites lutea) and Rubber Vine (Rhabdadenia biflora) are also often found on Buttonwoods in this association.

Moving upland, the transitional zone grades into hammock with its dense association of trees and shrubs, closed canopy, vertical structure and absence of graminoids and fleshy halophytes. The landward extent of the tides is marked by the accumulation of litter on the forest floor and generally corresponds to the hammock boundary. Often, there are small islets of low hammock within the transitional zone vegetated by small, salt tolerant trees and shrubs, e.g. Joewood (Jacquinia keyensis), Wild Dilly (Manilkara bahamensis), Mayten (Maytenus phyllanthoides), Black Torch (Erithalis fruticosa), Saffron Plum (Blumelia celastrina), and Poisonwood (Metopium toxiferum). These plants are common elements of the low hammock association.

Plants occurring in transitional zone that have been categorized by state and/or federal agencies as endangered or threatened include:

Golden Leather Fern	Acrostichum aureum
Leather Fern	Acrostichum danaeifolium
Geiger Tree	Cordia sebestena
Dollar Orchid	Encyclia boothiana
Butterfly Orchid	Encyclia tampensis
Joewood	Jacquinia Keyensis
Pride of Big Pine	Strumpfia maritima
Bay Cedar	Suriana maritima
Twisted Airplant	Tillandsia circinata
Banded Wild Pine	Tillandsia flexuosa
Worm Vine Orchid	Vanilla barbellatus

While not presently so designated, the Tamarindillo (Acacia choriophylla) should similarly be afforded endangered status in the Keys, as its population is comprised of a single mature specimen and several seedlings in a transitional wetland on Sugarloaf Key.

The transitional zone supports a fauna somewhat different from that of mangrove systems, but there are a number of animals that feed in both tidal areas. The most frequently observed invertebrates are various species of insects, molluscs and crustanceans. Of the latter, the fiddler crab (Uca spp). is often found in the salt marshes and barrens where there is adequate soil for burrowing. The white peanut snail (Cerion spp.) is often found in large numbers on the marsh floor or climbing through the low-lying vegetation; Ram's Horn Snails and the gastropods Cerithidea and Melampus are also very common in the marsh. A chartered herpetofauna of Keys transitional wetlands include:

Green Anole	Anolis carolinensis
Key West Anole	Anolis sagrei stejnegeri
Six-lined Racerunner	Cnemidophorous s. sexlineatus
Black Racer	Coluber constrictor
Red Rat Snake	Elapha guttata
Eastern Diamondback Rattlesnake	Crotalus adamanteus
Cuban Treefrog	Hyla septentroinalis
Rough (Keeled) Green Snake	Opheodrys aestivus

A number of mammals use transitional wetlands. The endangered Key deer (Odocoileus virginianus clavium), and the endemic Key Vaca Raccoon (Procyon lotor auspicatus), listed as threatened by the state, feed in salt marshes and Buttonwood scrub. The habitat of the recently described (Spitzer and Lazall, 1978) Silver Rice Rat (Oryzomys argentatus; state endangered) has been redefined to include the low intertidal zone, salt marshes, and the Buttonwood transitional community (Spitzer, unpublished M.S.). Results obtained from Spitzer's recent (1984) trapping studies indicate that this rodent forages and nests in transitional wetlands, as does the endemic Keys' marsh rabbit, Sylvilagus palustris hefneri (Lazell, 1984).

The importance of Keys' wetlands to wading bird populations has long been recognized by wildlife biologists. Virtually every wading bird species resident in the archipelago forages in tidal wetlands. Scientists from the National Audubon Society have been studying Keys birds for over 40 years and are presently continuing a three-year study on Florida wading bird ecology. This study is providing documentation for the importance of transitional wetlands to these birds. The unpublished results (Sprunt and Powell, Pers. Comm.) demonstrate that:

> ". . . water cycles characteristic of Florida Bay place an exceptionally high level of importance on transition zone habitats throughout the Keys for the survival of wading birds. The topography of Florida Bay and extreme South Florida in general restricts water flow between the Keys, the Atlantic

Ocean and the Gulf of Mexico. As a result, water levels in Florida Bay fluctuate seasonally and the Bay remains continually flooded for several weeks and even months of the year. During these periods, most wading birds are unable to feed in their usual feeding areas because the water is too deep for them to wade. Consequently, they are forced to seek alternative feeding sites and therefore, move into the high marsh and transition zone habitats which are generally covered by shallow water at that time. During these periods, the existence of undisturbed transition habitat is critical to the survival of birds that at other times feed on seagrass meadows adjacent to the Keys. This seasonal dependence on habitats that are available primarily on the main line keys is illustrated in the data we have collected on wading bird abundance in Florida Bay. During the months of September and November, when Florida Bay water levels were high, the birds were absent from the Bay and were feeding instead in transitional zone habitats."

Wading birds that feed in transitional wetlands include:

Roseate Spoonbill	Ajaia ajaja
Great White Heron	Ardea herodias occidentalis
Great Egret	Casmerodius albus
Little Blue Heron	Egretta caerulea
Snowy Egret	Egretta thula
Reddish Egret	Egretta rufesceus
Tricolored Heron	Egretta tricolor
Green-backed Heron	Butoredes vivescens
White Ibis	Eudocimus albus
Black-crowed Night Heron	Nycticorax nycticorax
Yellow-crowned Night Heron	Nyctanassa violacea
Glossy Ibis	Plegadis falcinellus

Disturbances

The ecological history of Keys' wetlands is often a reflection of natural disturbance and the biota's collective response to these extreme environmental pulses. Salt marshes are often formed by the action of storms and hurricanes, which create natural impoundments on the periphery of these islands. The impounded wetlands contain saline, marl soils that are subsequently wetted by storm overwash or seasonal rains. The most destructive disturbance is that of hurricanes. Hurricanes often reset the time line of ecological succession, as in the case of the 1960 hurricane Donna. According to Craighead (1971), who reported the effects of Donna on Everglades National Park:

> "...the seed of batis immediately germinated and formed an almost continuous ground cover throughout the entire saline zone on low tidal lands where the mangrove stands had been killed and sunlight reached the new soil left by the storm tide. Batis is a light-demanding plant that was relatively scarce before Hurricane Donna in all well stocked mangrove forest areas. The seeds float and were widely distributed in the fresh mud deposits. By the end of the second summer following this storm, pratically the entire area of destruction could be distinguished from the air by the yellowish-green ground cover of this scrubby plant.
>
> The stems of batis loop over and intertwine to reach a height of 2 to 3 feet, making a tangle that is very difficult to penetrate. This mat is an effective hindrance to the growth of mangrove seedlings."

A similar phenomenon occurs when mangroves are removed or impounded by man. The fleshy halophytes suppress mangrove development, but are eventually "shaded out" once the mangroves become re-established. If, on the other hand, the soils of the impounded area remain hypersaline, mangroves will not survive and a salt marsh or barren will result. Buttonwood areas of the Keys and Everglades National Park that have been cleared for charcoal production now contain a flora dominated by graminoids, herbs and small shrubs. The Buttonwoods are now recolonizing and the characteristic seral progression is progressing.

A less dramatic disturbance occurs in salt marshes as a result of compacting of the vegetation and soils by heavy equipment or off-road vehicles. Salt marsh plants have shallow root systems that form a rhizosphere only a few inches below the soil surface. This confines the feeding rootlets to the zone wherein salinities are less than that of the deeper soil. This stratification results from the leaching action of rainwater that percolates downward, or drains off, carrying with it the accumulated salt load. Moreover, the shallow marl soils tend to compress under load, diminishing the extent of interstitial space between soil particles, which is important for gas, water and nutrient exchange. Thus, one finds persistent tracks or scars in salt marshes that are the impact marks of vehicles that have killed the vegetation and created conditions inimical for recolonization, a situation quite similar to the "prop-scarring" of marine seagrass beds by power boats.

Filling areas adjacent to transitional wetlands can produce adverse impacts by interrupting tidal flow and possibly changing salinity. Impoundments in adjacent areas may have simi-

lar effects. Examples include construction of roads and subdivision between transitional wetlands and the source of tidal sheet flow for these areas.

6.
TROPICAL HARDWOOD HAMMOCKS

Tropical hardwood hammocks constitute the climax terrestrial community of South Florida and the Keys. These forest systems occur as isolated stands of hardwoods amid freshwater or saltwater wetlands. The flora of these communities is largely derived from tropical species of the West Indies rather than from the temperate forms that characterize the plant communities of the Florida peninsula generally.

In the Everglades, these "tree islands" may be seasonally flooded, but elsewhere they tend to remain above water except after severe storms or hurricanes. The soil of these hammocks consists mostly of a layer of partially decomposed organic matter resting directly on a porous limestone substrate. This thin film of organics is the principal physical resource that enables hammocks to accommodate a flora that is adapted to mesic - and not xeric - conditions. The maintenance of this organic layer is therefore critical to the existence of tropical hardwood hammocks. The closed canopy of hammocks is insulative, moderating thermal extremes (Olmstead and Loope, 1984) and reducing the loss of soil moisture. Keys hammocks are also characterized by a heterogeneity that is indirectly attributable to periodic fire and hurricanes. These natural impacts interrupt succession in all or a portion of the hammock to produce a mosaic of seral stages within or among hammocks.

Within the hammocks, most plant species occur as "clumps" rather than being characterized by random or uniform distribution. In tropical hardwood hammocks as with other tropical New World forests, there is a positive correlation between degree of clumping and rarity (Hubbell, 1979), which means that very rare forms may occur only in one or two places and thus are inordinately susceptible to elimination.

Biota

South Florida's tropical hardwood hammocks have been subcategorized as high hammocks and low hammocks (Davis, 1943; Alexander, 1958) on the basis of their vegetation. In the Keys, low hammocks occur approximately plus or minus 1-2 meters above sea level, and high hammocks approximately plus or minus 2-5 meters (Karen Achor, Pers. Comm.). Thus, one hammock type may grade into the other at their common edge.

In Monroe County, high hammocks occur primarily in the upper Keys and are rare elsewhere. Mature high hammocks are extremely rare, with the most mature apparently being limited to North Key Largo and Lignum Vitae Key. A typical high hammock

canopy ranges from 4-10 meters high with taller canopy species such as Mahogany (Swietenia mahagoni) protruding 3-7 meters above the canopy. Other canopy emergents include Poisonwood (Metopium toxiferum), Jamaica dogwood (Piscidia piscipula), Shortleaf Fig (Ficus citrifolia), and Wild Tamarind (Lysiloma latisiliquum). Shorter canopy species include Pigeon Plum (Coccoloba diversifolia), Willow Bustic (Bumelia salicifolia) and Black Ironwood (Krugiodendron ferreum). Smaller trees like White Stopper (Eugenia axillaris) and Crabwood (Ateramnus lucidus) may be part of the canopy or a discontinuous shrub layer. The sparse ground cover includes Snowberry (Chiococca parvifolia), Passionflower (Passiflora suberosa) and other herbaceous forms. Various bromeliads, orchids, and ferns occur as epiphytic forms.

Low hammock species tend to be smaller than those of high hammocks, and the canopy is correspondingly lower. The canopy may be so low (2-3 m), in fact, that there is little distinction between canopy and subcanopy. In his studies of West Indian Hammocks, Beard (1955) attributes this feature and also the high occurrence of thorny species and/or forms with small, simple, stiff leaves to decreased soil moisture. In low hammocks, Buttonwood (Conocarpus erecta) joins the canopy and species such as Wild Dilly (Maninkara bahamensis), Jamaica Caper (Capparis cynophallophora), and Saffron Plum (Bumelia celastrina) are usually found only in low hammock systems. Species such as Prickly Pear Cactus (Opuntia stricta), Sea Grape (Coccoloba uvifera) and Cabbage Palm (Sabal palmetto) are restricted primarily to low hammocks but can occur in the upper edge of transitional wetlands.

Of the many plant species native to the tropical hardwood hammocks of the Keys, 33 are classified by state and/or federal agencies as endangered or threatened. These are shown on Table 1.

The environment provided by the flora of tropical hardwood hammocks is a major determinant of the assemblage of animal species that inhabit these communities. Because of their uniqueness and restricted occurrence, tropical hardwood hammocks harbor many endemic or very restricted animal species, including several of the Keys' threatened or endangered species.

While amphibians are not abundant in Keys hammocks, many reptiles may be found. These include the Box Turtle (Terrapene carolina bauri), Key Mud Turtle (Kinosternon bauri bauri), the endemic Keys Mole Skink (Eumeces egregius egregius), Coral Snake (Micrurus fulvius fulvius), Eastern Diamondback Rattlesnake (Crotalus adamanteus), Key Ringneck Snake (Diadophis punctatus acricus), Eastern Indigo Snake (Drymarchon corais couperi), Florida Brown Snake (Storeria dekayi victa), Miami Black-headed Snake (Tantilla oolitica), the Florida Ribbon Snake (Thamnophis sauritus sackeni) and the Rosy Rat Snake (Elaphae guttata guttata). While some of these reptiles apparently occur throughout the Keys, others are restricted to only a portion of the archipe-

lago. The coral snake, for instance, is apparently limited to upper and middle Keys hammocks.

Many species of birds use tropical hardwood hammocks. Those known to nest in Keys hammocks are:

Red-shouldered Hawk	Buteo lineatus
Osprey	Pandion haliaetus
Mourning Dove	Zenaidura macroura
Ground Dove	Columbigallina passerina
Mangrove Cuckoo	Coccyzus minor
Yellow-billed Cuckoo	Coccyzus americanus
Screech Owl	Otus asio
Chuck Will's Widow	Caprimulgus carolinensis
Pileated Woodpecker	Dryocopus pileatus
Common Flicker	Colaptes auratus
Red-bellied Woodpecker	Centurus carolinus
Gray Kingbird	Tyrannus dominicensis
Great-crested Flycatcher	Myiarchus crinitus
Carolina Wren	Thryothorus ludavicianus
Mockingbird	Mimus polyglottus
Brown Thrasher	Toxostoma rufum
White-eyed Vireo	Vireo griseus
Black-whiskered Vireo	Vireo altiloguus
Red-winged Blackbird	Agelaius phonicius
Common Grackle	Quiscalus guiscula
Cardinal	Richmondena cardinalis

Within the Keys, the range of some species is quite limited. The Pileated Woodpecker and Carolina Wren, for instance, are known only from Key Largo.

Endangered or threatened bird species using tropical hardwood hammocks include the Peregrine Falcon (Falco peregrinus), which hunts along the hammock edge or treetops, and the White-crowned Pigeon (Columba leucocephala). The latter is a spring and summer resident of the Keys that is not found elsewhere in the United States. They nest in mangroves but feed in hammocks, especially on the fruit of Poisonwood Trees.

Mammals that use Keys tropical hardwood hammocks include the Opossum (Dildelphis marsupialis), Gray Squirrel (Sciurus carolinensis matecumbei), Raccoon (Procyon lotor), Marsh Rabbit (Sylvilagus palustris hefneri), Hispid Cotton Rat (Sigmodon hispidus), Least Shrew (Cryptotis parva), and Bobcat (Felis rufus). Four subspecies of mammals that inhabit Keys hammocks are classified by state and/or federal agencies as endangered or threatened. These are:

Key Largo Wood Rat	Neotoma floridana smalli
Key Largo Cotton Mouse	Peromyscus gossypinus allapaticola
Key Vaca Raccoon	Procyon lotor auspicatus
Key Deer	Odocoileus virginianus clavium

Originally, the Key Largo Wood Rat and Key Largo Cotton Mouse were apparently limited to hardwood hammocks in North Key Largo. Both were introduced to Lignum Vitae Key in 1970 and while population levels for the mouse have not been determined, the wood rat seems to be prospering. The Key Vaca Raccoon is known to occur from Grassy Key to Key West. The Key Deer is found only on the lower Keys at present. Key Deer use several communities for feeding, but show a preference for open hammocks and pinelands (Layne, 1974).

Of the many invertebrates inhabiting Keys hammocks, two are endangered forms. These are the Stock Island Tree Snail (Orthalicus reses reses) and the Schaus Swallowtail Butterfly (Heraclides aristodemus ponceanus). The former was originally restricted to Stock Island and Key West, while the latter is known only from North Key Largo and Elliott Key where it deposits its eggs primarily on Torchwood. Some color forms of the Florida Tree Snail (Liquus fasciatus) are restricted to specific hammocks, and it appears that habitat destruction by collectors have eliminated some forms.

Disturbances

Impacts that affect hammocks on the Keys are varied and include natural events such as hurricanes and fires. Man-induced impacts include activities such as land clearing, dredging, ditching, filling, and the introduction of exotic plants. The nature of these impacts depends on the integrity and size of the hammock and its wildlife. Recovery from the impacts depends on the condition, size, and amount of surrounding hammocks and wetlands, or the type of development in adjacent land.

Due to the intricate relationships of hammock species, seemingly insignificant impacts can result in extensive repercussions. For instance, loss of a large Mahogany adversely affects the Mahogany Mistletoe (Phoradendron rubrum) that grows only in the tops of mature Mahogany trees.

As previously emphasized, hurricanes are the most important natural force that impacts terrestrial ecosystems in the Florida Keys. The degree of disturbance, of course, varies with hurricane intensity, but severe hurricanes can devastate hardwood hammocks so that many years or even decades may be required for recovery. The sloping outline of a mature hammock canopy may deflect winds (Craighead, 1974); thus, hurricane impact is more severe if the hammock edge is not intact. Fires also can alter hammocks for long periods since they may destroy the shallow organic "soil" that is essential for the structure and function of these ecosystems. Usually, though, natural fires result from lightning strikes during the wet season when the most humus is less likely to burn extensively. Eventually, however, successional changes will reestablish the species assemblage characteristic of the original system. This is attributable largely to

the fact that such natural catastrophes are recurring phenomena to which target species have evolved a genetic accommodation. The cumulative result of these adaptations generates a regular and orderly successional recovery following such events.

Alterations mediated by human activity are usually more enduring and sometimes permanent. By 1974, over 50% of South Florida's tropical hardwood hammocks had been destroyed (Robertson & Kushlan, 1974). Land clearing, dredging, ditching, and filling modify the edaphic conditions that are essential to hammock restoration. Further, these activities remove the propagules that constitute the gene base for successional recovery. The extensive introduction of exotic plants further complicates the prospects of recovery from natural or human-caused impacts since some of these tend to outcompete and eventually replace some native species that are links in the seral recovery sequence that would otherwise generate a hammock climax. Brazilian Pepper (Schinus terebinthifolius) is one such troublesome weed. While it seems incapable of establishing a toehold in unmodified hammocks, it rapidly invades altered hammock areas and may delay or even prevent recovery depending on the severity of disturbance. In part, the vulnerability of hammocks is attributable, as mentioned, to the easily destroyed meager soil resource that is the edaphic foundation of its fragile trophic structure. But this vulnerability is further attributable to the hammocks' isolation and discontinuity, which can make recruitment of successional forms difficult and thereby retard or prevent reestablishment of a hammock climax. The speed and likelihood of recovery are inversely proportional to the distance separating the altered area from an unaltered system from which recruitment can occur.

The incidence of filling in uplands appears to be increasing. This occurs for a variety of reasons including, leveling for vehicular use, septic tank drainfields, and to raise ground level to elevation required of structures by flood hazard regulations. Because of the differences in substrate, it is likely that recolonization of abandoned fill sites will result in a species assemblage that differs from the biota of the original hammock.

Mosquito control activities also result in the degradation of hammocks. Mosquito ditches provide avenues for saltwater intrusion and invasion by exotics; mosquito spraying affects pollinators as well as mosquitoes, especially the Schaus swallowtail butterfly and possibly the Florida Tree Snail.

Road construction has seriously affected hammocks, both directly and indirectly. In addition to the direct destruction of hammock acreage, road construction dissects and thereby fragments these systems. On North Key Largo, for example, all hammocks are dissected by U.S. 1 or C-905, most through (or close to) the center. The increased access thus provided to hammocks results in further indirect environmental damage by increasing storm damage, invasion of exotics, soil dessication, collecting, illegal dumping, fire, vandalism, and wildlife mortality.

Removing the understory and ground cover from hammocks is becoming a common practice in the Keys. This practice, locally called "grubbing out," provides visual access, increased airflow, and space for planted colorful exotics. This severely degrades hammocks by direct elimination of smaller plants which may serve as food or nectar sources for wildlife (including the young of canopy species), reduction of wildlife habitat, and increased exposure to the dessicating influences of wind and light.

Table 1:
SPECIES OF KEYS' HAMMOCKS PRESENTED LISTED AS ENDANGERED OR THREATENED ON STATE/FEDERAL LISTS*

Scientific Name	Common Name
Acrostichum aureum	Golden Leather Fern
Acrostichum danaeifolium	Leather Fern
Chrysophyllum oliviforme	Satinleaf
Cereus gracilis	Prickly Apple Cactus
Cereus pentagonus	Barbed-wire Cactus
Cereus robinii	Tree Cactus
Clusia rosea	Balsalm Apple
Coccothrinax argentata	Silver Palm
Cordia sebenstena	Geiger Tree
Cupania glabra	Cupania
Encyclia boothiana	Dollar Orchid
Encyclia tampensis	Butterfly Orchid
Eugenia confusa	Redberry Stopper
Guaiacum sanctum	Lignum Vitae
Hippomane mancinella	Manchineel
Jacquinia keyensis	Joeweed
Opuntia stricta	Prickly Pear Cactus
Polypodium heterophyllum	Vine Fern
Polypodium phyllitides (Campyloneuron)	Strap Fern
Pteris longifolia var. bahamensis	Ladder Brake
Salvia blodgettii	Blodgett's Sage
Swietenia mahagoni	Mahogany
Thrinax morrissii	Keys Thatch Palm
Thrinax radiata	Florida Thatch Palm
Tillandsia balbisiana	Reflexed Wild Pine
Tillandsia circinata	Twisted Air Plant
Tillandsia fasciculata	Wild Pine
Tillandsia flexuosa	Banded Wild Pine
Tillandsia setacea	Needle-Leaved Airplant
Tillandsia utriculata	Giant Wild Pine
Tillandsia valenzuela	Soft-Leaved Wild Pine
Vanilla barbellata	Vanilla Orchid
Vittaria lineata	Shoestring Fern

* Endangered status is shown on Table 2 on "Threatened and Endangered Plants of the Florida Keys."

7.
DISTURBED LANDS

BACKGROUND OF MONROE COUNTY VEGETATION MAPPING

The vegetation mapping program used two pre-existing sets of vegetation maps as its data sources:

1) The Florida Keys Hardwood Hammock Atlas, developed in 1977 as part of a project sponsored by the Florida Cooperative Extension Service and the National Audubon Society;

2) Vegetation base maps for the Florida Keys Coastal Zone Management Study, developed in 1974 by the Florida Coastal Coordinating Council.

Both of these map sets were drawn at a scale of 1" = 2000', which is the same scale as the County's land use base maps.

Because both of these map sets are somewhat outdated with regard to development, the current extent of developed lands was taken from more recent maps from the Department of Community Affairs, also drawn at the same scale (1" = 2000').

The resulting maps of vegetation and natural features were extensively checked and revised by the Planning Department's biologists, who are familiar with the vegetation in many areas of the Keys as a result of work experience. Available aerial photography (black and white, 1" = 600', Real Estate Data, Inc.) was also used as another source of information.

Land that has been defined as disturbed or scarified is coded as one of seven subcategories of the 740 series on the Existing Land Conditions maps prepared by the Monroe County Planning and Zoning Department. The mapping of a parcel of land as disturbed is derived from the conclusion, based upon these analyses, that the parcel manifests clear signs of environmental disturbance which has had an observeable effect on the structure and function of the natural community which existed on site prior to the disturbance. The definition of each of the subcategories explicitly states that the disturbed condition of the parcel is the result of "human activities."

This narrative describes the existing conditions of each of these subcategories and the developmental or successional sequences expected to occur for each subcategory. The environmental effects of the activities that resulted in these disturbed conditions on the pre-existing natural communities, and their consequences for the Florida Keys ecosystem, is also discussed elsewhere in the Plan. It is not the purpose of this discussion to judge whether or not the creation of disturbed lands is in the public interest. The purpose is to examine the structure and

function of the existing conditions and to predict the ecological future of these lands, their biota and their impact upon other natural communities of this ecosystem.

Disturbance

In order to evaluate "disturbed lands" or the impact of a particular disturbance on a natural system, one has to have a reference base from which to extrapolate impact assessments. A pristine or undisturbed natural system operating at 100% of its functional potential is generally used as the baseline. This premise is based upon the assumption that, for a particular time and place, the biota of a system is functionally adapted to the physicochemical-biological conditions of a site. That is, for a particular seral or developmental stage, the on-site biota is exchanging information, utilizing energy and cycling nutrients at an optimal level. As the environment changes, selective forces favor the best adapted genetic variants from the various species populations and the living community slowly fine tunes itself to the changing conditions. The community moves through an orderly series of biotic associations, adapting to changing conditions, which follow each other, in time, on a particular site. Each seral stage in this successional sequence has its character species assemblage which modifies the site in a manner that prepares it for the succeeding sere. Given adequate time, the collective response of the system is to ultimately achieve the optimal level of function possible for a given stable site; this is known as the ecological or successional "climax." In the Florida Keys, climax communities include the coral reef complex, the seagrass community and the tropical hardwood hammock.

An optimally functioning, complex natural system is not only intrinsically efficient, but provides benefits to adjacent natural systems. These take the form of exported productivity; filtering functions for nutrients and pollutants that would otherwise "load up" other systems, temporary habitat for transient species or juvenile forms, and a host of benefits for the human community.

Adverse natural or man-made impacts disrupt the energy and information linkages and diminish the structural complexity of a balanced system. As a result, levels of efficiency drop, available energy is wasted and communication links to other natural and man-made systems are lost. A good analogy is that of the fishing net. A net with an intact mesh can catch, if properly set in time and space, an optimal number of fish or shrimp. If there are holes in the net, then animals pass through and the number of pounds landed drops; the more holes, the lower the catch.

An adverse impact or stress imposed upon a biotic element evokes a response from that element which is directly related to the kind and intensity of the stress. For instance, deer hunting alters the population size of a specified target

population, whereas pesticide spraying affects numerous non-target forms. The response may be indirect if the impact alters the physico-chemical environment of the site or adjacent area. Fishing, for example, directly affects population levels of certain species, but the filling of mangrove communities also affects these populations by diminishing their available food and juvenile habitat.

Evaluation of response to impact or stress reveals that the manifestation may occur at one or several levels of biological organization. At the level of the individual, stress may affect an organism in several ways. It may reduce or eliminate its ability to reproduce; it may influence its metabolism; or it may alter its behavior. If it fails to reproduce, its contribution to the population's gene pool is lost. If its metabolism is affected, it may cease to contribute a portion of its productivity to the system. If its behavior is affected, it may move out of the area. If the stress is severe it may die.

At the level of the species population, stress can also evoke similar functional responses. A low level of stress may impact only the most sensitive variants of a population, eliminating them or diminishing their reproductive success; this alters the gene pool of this species population. The population may regain its original level of individuals although the gene pool has been changed. At greater levels of stress, even the more tolerant individuals suffer from physiological, behavorial or reproductive changes in which may result in the extirpation of that population.

The scenario for an entire species is similar, with different populations varying in their tolerance to a particular impact due to genetic differences. Minor stress may result in genetic losses or even the extirpation of species populations whereas intense or long term stress may result in extinction of an entire species.

At the community level, environmental impacts affect several species populations. Some populations may decrease in number or productivity, while others may actually increase as a result of less competition. In some cases, an entire niche may open up allowing for the colonization by an opportunistic species. A Keys' example is the colonization of spoil areas by least terns (Sterna antillarum) -- a bird which nests in gravel. In general, however, stress impacting entire communities manifests in lowered species diversity, less efficient community metabolism and diminished system stability. In extreme cases, a natural, complex and efficient vegetative association is replaced by monocultures of exotic plants that have not co-evolved with the resident wildlife and thus provide little benefit to these creatures. Stresses, which have adverse impacts upon entire communities, eliminate the benefits of normal function to other natural and man-made systems. A well documented example is the impact of wetland community loss on nearshore sport and commercial fisheries.

The concept of "disturbance" to natural systems has undergone intensive examination by scientists over the past two decades. The emerging conclusion is that not all disturbances are "bad." Fire, for instance, is now recognized as a natural disturbance affecting all terrestrial and wetland communities in southern Florida (Hofstetter, 1974). Craighead (1971) has pointed out that fires play a great part in the development and survival of many of the plant communities of this region. Fires preserve the dominance of sedges and grasses in the Everglades which, in the absence of fire, would be shaded out by the less fire-resistant species. Fires help maintain pinewoods, in the Keys, by eliminating tropical hardwoods which would otherwise shade and crowd out the young pines. Periodic brush fires eliminate litter, which, if allowed to accumulate, would ultimately fuel a destructive crown fire which would kill pines and wildlife. The native plant and animal populations have evolved with this type of natural disturbance and actually derive benefit from its effects. A pinelands controlled by fire is known as a "fire sub-climax" because fire arrests the succession before it develops to the hammock climax.

Tropical storms are another type of natural disturbance that recurs in the Keys. Although a major hurricane can devastate natural systems, they are adapted to this type of perturbation and eventually recover even after a setback to an earlier sere. A major benefit of tropical storms is the recharge of aquifers in South Florida which is extremely beneficial to native vegetation and wildlife.

Although an ecosystem may ostensibly suffer or be set back by a natural disturbance, it generally recovers to its pre-existing condition following a regular and orderly successional sequence. This is because the biota of a system, that is subject to periodic natural disturbances has evolved, over long periods of time, the mechanisms that allow it to accommodate to these environmental pulses. Man-made disturbances, on the other hand, represent very recent influences for which the genetic response has not evolved. Moreover, these impacts tend to have permanent rather than short term effects on the physical structure of the environment. Dredging and filling, for instance, significantly alter the substrate upon which the plant community is so dependent and creates soil, drainage and salinity conditions entirely different from the historic. This type of disturbance is permanent as opposed to an episodic natural disturbance. A persistent and high water table created either by a natural or man-made impoundment can retard succession resulting in an "edaphic sub-climax."

Disturbed lands in the Keys have been created by a number of human activities. These include:

1. Placement of fill or dredge spoils on wetlands or upland communities;

2. Clearing of vegetation;

3. Removal of topsoils;

4. Impoundment of wetlands;

5. Drainage of surface waters;

6. Blockage of surface drainage;

7. Restriction of tidal circulation;

8. Introduction of exotic vegetation;

9. Evacuation or dredging of uplands or wetlands.

These activities affect the physical environment as well as the on-site biota. Moreover, there are usually secondary effects which impact off-site communities and which may have their manifestations in the future. For instance, a spoil bank in a subtidal habitat may severely impact the water quality in surrounding subtidal and intertidal habitats, resulting in long term degradation of environmental conditions some distance from the spit itself. The disturbed condition most often represents a significant diminution of both community structure and function relative to the pre-altered state of the parcel. For example, the physical effects of topsoil and vegetation removal from a tidal wetland would include:

a. Faster surface runoff;

b. Increased subsoil erosion;

c. Loss of soil nutrients;

d. Increased nearshore sediment loads;

e. Decreased light penetration to nearshore bottom communities;

f. Loss of habitat diversity;

g. Increased salinity of interior wetland soils.

The physical effects of placement of fill within a tidal wetland would include:

a. Interference with surface drainage pattern;

b. Restriction of tidal circulation;

c. Increased nearshore turbidity;

d. Reduced light penetration nearshore;

e. Loss of habitat diversity;

f. Changes in edaphic conditions;

g. Reduced water quality.

The response of the biological community to these effects can be evaluated at the species, population, and community levels. Both structural and functional reactions can be measured. Thus, analysis of observable impacts upon each of the Keys' community type allows for a projection of expected trends within an already stressed community, or anticipated impacts upon pristine systems. Review of the literature dealing with mainland scenarios allows for some extrapolation from analogous situations.

The ecological literature of South Florida documents the successional impact of disturbance. Both human and natural environmental alterations have re-directed or delayed primary succession and have caused a sequence of events known as "secondary succession" to take place. At its extreme, secondary succession is the sequence of events which transpires upon a site from which the natural community has been obliterated, i.e. a bare area open to invasion by colonizing plants and animals. Secondary succession may be initiated by: filling, clearing, farming, lumbering, impounding, draining, fire or hurricane. Changes in hydroperiod, water tables and edaphic factors have more subtle impacts on successional sequences.

The impacts of drainage on natural systems in the Florida Keys have been especially profound. This is due to the limited acreage of freshwater wetlands in the area and to the extent of drainage practice throughout the Keys. Drainage of freshwater wetlands in the lower Keys has resulted, in part, from the widespread mosquito ditching that took place during the last three decades. The intent of ditching was to drain standing water from upland areas and to provide tidal circulation into these areas. This activity is designed to eliminate mosquito habitat and provide watercourses for predaceous fishes to gain access to their prey.

What ditching has accomplished is the draining of freshwater marshes and the introduction of seawater into upland systems which are either intolerant or only slightly tolerant of this saline influence. Salt water intrusion impacts both surficial and groundwater resources. The cumulative effect has been to eliminate freshwater marshes or to modify the habitat so that it no longer supports a freshwater biota. In some cases, blocked mosquito ditches actually result in the creation of freshwater wetlands which support a characteristic biota, including mosquitos and occasionally alligators.

A somewhat more subtle effect of drainage has been that which has resulted from the dredging of navigable waterways and

borrow pits on adjacent systems. Obviously, the dredging of a canal or quarry obliterates the on-site community. But what is less apparent are the off-site effects. Wang (1978), in studies of the effects of drainage canals on wetlands, has shown that drainage canals can lower surface water levels at a distance of up to one mile in the surrounding landscape. Lowering of groundwater levels changes historic water regimes and edaphic conditions in wetlands and diminishes available soil moisture in the rhizosphere of upland systems.

Solution formations, which hold water during the dry season and because they are connected to shallow freshwater lenses and aquifers, are severely impacted by activities which lower groundwater supplies. Faunal elements, such as the endangered Key deer, mud turtle, American alligator, and a variety of reptiles and amphibians, depend upon these water sources during the lengthy dry season. Direct or indirect drainage of ponds destroys these areas as feeding habitat for both resident and transient bird populations. Thus, impacting the groundwater table may have secondary effects upon wildlife.

Natural or man-made impoundments, in either wetland or upland systems, alter edaphic conditions to the extent that the disturbed area now selects for a more hydrophilic biota. If the impoundment allows for persistent standing water, this habitat will select for plants which will tolerate long periods of submersion, e.g. widgeon grass (Ruppia maritima). Ultimately, the secondary successional sequence will reach an edaphic sub-climax that supports a community of hydrophytes, fishes and small aquatic invertebrates. If the impoundment maintains an adequate volume of water, the effects of seasonal fluctuations in temperature, salinity and water depth will not be severe, and the impoundment may also support a diverse, permanent avifauna.

Thus, the consequence of impoundment could be an exchange of habitat types. If the aquatic niche can be occupied by a diverse biota, it might exhibit valuable structural and functional attributes comparable or superior to its predecessor, although the cast of players might be significantly different. The time frame for this hypothesized successional sequence would always be site specific.

Another influence on community succession is that of invasive exotic plants which are now well established in South Florida. In the Keys, the most problematic invasive exotics are: Brazilian pepper (Schinus terebinthefolius), Australian pine (Casuarina equisetifolia), Sapodilla (Manilkara zapoda) and leatherleaf (Columbrina asiatica). According to Alexander and Crook (1974), Schinus and Australian pine "....are aggressive competitiors toward native plants and once they gain a foothold in a community they can retard normal plant succession and even eliminate native species." Both Schinus and Australian pine may be allelopathic, i.e. may release chemicals into their surroundings that inhibit the growth of competing vegetation.

In a report entitled "Schinus in Successional Ecosystems of Everglades National Park" (Ewel, et al., 1982) the following conclusions are reported:

1. Schinus seedlings are remarkably tenacious and can survive for years in dense shade (such as within hammocks) where they grow very slowly. In openings, however, Schinus seedlings grow very fast. Even seedlings whose growth has been suppressed for years can respond to canopy openings with rapid growth.

2. Established seedlings grow fast in most young successional communities and grow slowly in most older communities.

3. Young successional communities are more susceptible to Schinus invasion than are old successional communities, and all successional communities are more susceptible than are mature, native communities. Undisturbed pineland is more susceptible to Schinus invasion than is undisturbed glade or wet prairie, and hammocks are less susceptible to invasion than are the other two undisturbed ecosystems.

Australian pine forests develop on filled land, disturbed beaches and tropical hammocks subjected to severe fires or vegetation removal. Schomer and Drew (1982) describe an Australian pine community as "....characterized by a monoculture of Australian pine forming a closed canopy layer approximately 12 to 15 m (40 to 50 ft.) high. Seedling and saplings are currently rare under the canopy and are generally uncommon along the margins of the forest. Understory vegetation is largely absent and the forest floor is composed of a dense layer of Australian pine litter and a few species of ubiquitous annuals. There are generally a few outliers within several hundred meters of the forest and these individuals are frequently reproductive trees."

The Everglades National Park research staff has also studied the impact of leatherleaf on Park vegetation (Olmstead, et al., 1981) and has observed that it forms pure stands, especially within buttonwood vegetation. The authors of this report consider it to be a "possible severe threat to native vegetation."

The following is a partial list of plants generally associated with disturbed sites in the Keys at early seral stages:

SCIENTIFIC NAME	COMMON NAME
Alternanthera philoxeroides	Chaff Flower
Andropogon glomeratus	Broom Sedge
Aster tenuifolius	Aster
Baccharis halimifolia	Saltbush
Bidens alba	Spanish Needles
Borrichia frutescens	Sea Daisy
Carica papaya	Papaya

Casuarina equisetifolia	Australian Pine
Cenchrus echinatus	Southern Sandspur
Chanmaesyce spp.	Spurge
Cirsium horridulum	Purple Thistle
Conocarpus erectus	Buttonwood
Crotalaria pumila	Rattlebox
Dactylocten aegyptium	Crowfoot Grass
Distichilis spicata	Saltgrass
Eupatorium capillifolium	Dog Fennel
Eustachys petraea	Finger Grass
Fimbristylis spathaceae	Hurricane Grass
Flaveria linearis	Yellowtop
Heliotropium angiospermum	Dog's Tail
Lantana involucrata	Wild Sage
Lepidium virginicum	Pepper Grass
Leucaena leucocephala	Leadtree
Melanthera aspera	
Paspalum distichum	Joint Grass
Phyla nodiflora	Creeping Charlie
Pluchea odorata	Bushy Fleabane
Pluchea rosea	Marsh Fleabane
Pteridium aquilinum	Bracken Fern
Rhyncheletrum repens	Natal Grass
Schinus terebinthefolius	Brazilian Pepper
Setaria geniculata	Foxtail Grass
Sida acuta	Wireweed
Solanum bahamense	Bahama Nightshade
Solanum erianthum	Potato Tree
Sporobolus domingensis	Dropseed
Sporoblous virginicus	Dropseed
Stachytarpheta jamaicensis	Blue Porter Weed

CATEGORIES OF DISTURBED LANDS

Numbers correspond to codes on the Monroe County Planning Department's "Existing Conditions" maps.

Bare/Vegetation Unknown - 740.0

These are areas that have been disturbed by human activities (e.g., deposition of fill, land clearing) on which there are large areas of bare substrate, or where the site is obviously disturbed but the vegetation could not be determined by ground-truthing because the site was not accessible to County personnel.

Areas which fall into this category have been created as a result of placement of fill material on wetland or upland systems or as a result of vegetation removal by heavy equipment. In the latter circumstance, considerable topsoil is also removed during land clearing operations leaving exposed subsoils and/or bare caprock. Areas coded as 740.0 contain only the vestigial remnants of the pre-disturbance natural community.

If both vegetation and topsoil have been removed, then secondary succession begins on an essentially barren substrate. Physical conditions on this type of site fall into the extreme range, since the full impact of sun, wind and rain impinge directly upon the surface of the site which does not receive the benefit of the ameliorating influence of vegetation or soil. The following physical conditions probably prevail on these sites:

1. Extreme diurnal and seasonal temperature fluctuations;
2. Rapid runoff or infiltration of rainwater and a consequent diminished potential for groundwater recharge;
3. Depressed water table;
4. Low soil moisture levels in the rhizosphere;
5. Macro and micro nutrient deficiencies in soils;
6. Extreme scouring and desiccating influence of the wind.
7. Excessive salinity in low areas due to periodic tidal overwash or by capillary actions from underlying saline water.

The removal of all vegetation eliminates food, cover and nesting sites for wildlife. At best, there will remain an exceptionally depauperate faunal association.

If limerock fill material or dredge spoils are placed upon cleared land, the resultant physical conditions will be only slightly different than those listed above. If enough fill is placed in a tidal wetland to elevate the surface above the influence of normal tides, then the site will no longer receive the benefits of tidal circulation. If this is the case, then a tidal wetland community could never re-emerge on the site. If the site is elevated to a height which causes only a diminution of tidal exchange, then a re-established wetland association will probably be functionally different from the historic community and possibly structurally dissimilar. In this case, a community characterized by salt marsh and/or buttonwood association species would replace the pre-existing biota.

The physical conditions characteristic of barren, limerock fill areas are highly stressful for life. According to the results of numerous percolation tests conducted in the Keys, it appears that fresh fill material is quite porous and consequently does not retain moisture very well. Rainwater percolates rapidly downward below the rhizosphere and rates of stormwater runoff are high. Without the benefit of vegetational shading, seasonal and diurnal temperatures probably reach extremes on the fill surface

and light levels are exceptionally high due to the reflectivity of the almost pure white substrate. Moisture levels in the interstitial spaces of the fill are low and nutrient reserves are almost non-existent. Available soil water exhibits an alkaline pH due to the calcareous nature of the fill.

Due the the paucity of soil moisture and lack of nutrients, successful colonization and growth of vegetation in these areas will be prolonged. If only the original vegetation association has been removed but not the soil, then the secondary successional sequence will probably restore the community in 25 to 100 years. But when topsoils are removed or when limerock fill is placed on a site, the successional sequence takes much longer. After several years of exposure to sun-drying and rain, limerock fill often compacts to a very dense substrate through which water will only slowly infiltrate. It is very difficult for plants to colonize this concrete-like surface material.

Following obliteration of the natural community, there is an excellent probability that a monoculture forest of one of the exotic tree species, which have become so abundant in South Florida, will become established on the disturbed site. Australian pines are especially well adapted to colonization of soil-free cleared areas. Examples of Australian pine monocultures are found on cleared land throughout the Keys, especially on sites which have been filled. Since they are now ubiquitous almost everywhere in the Keys, there is an abundant seed supply available to colonize freshly cleared and filled land. This species can also propagate vegetatively, thereby claiming cleared land adjacent to existing stands without having to produce viable seed.

Schinus is another exotic that exploits cleared and filled environments. Viable seed and young seedlings probably exist in most hammocks awaiting (teleologically speaking) an opportunity to take over a cleared area. Its seeds are dispersed by animals, including birds, so that no area in the Keys is far from a seed source. This invasive exotic is remarkably shade tolerant and will survive in wetlands which are elevated only slightly above normal tides. Once established, Schinus tends to dominate the vegetation of an area, excluding native vegetation. Neither Schinus nor Australian pine provide feeding or nesting habitat for most Keys' birds.

If invasive exotics do not colonize and form monoculture forests on cleared land, the secondary successional sequence usually begins with the establishment of a seral stage dominated by an association of plants known as "pioneer species." This is a group which can tolerate environmental extremes and can thus gain a foothold on land which is inimical, at this point, to the growth and development of less tolerant forms. Most pioneering plants are graminoids or "weedy" species which grow best in full sun. (A list of these plants is appended to this narrative.) Once woody species become established, they generally shade out

the pioneers. In disturbed sites on the Keys, the type of pioneer association which develops depends to some extent upon soil salinities. If soils are saline or if the ground is tidally inundated, a salt tolerant flora emerges. On cleared hammock or pineland areas, a somewhat different association occurs.

Once the pioneer association fully develops, succession can proceed in a number of different directions. The direction is dependent upon a number of factors which may include additional natural or anthropogenic disturbances. Assuming that invasive exotics do not take over the site, and that it is not developed for homes, businesses, etc., a mature and natural system will eventually succeed on the site. The mature climax, or sub-climax in the case of succession to a pineland, will follow a number of intermediate seres, each building on the biophysical conditions created by the previous sere. Each successive sere, additional disturbance notwithstanding, will exhibit a higher level of complexity both structurally and functionally. If the area is maintained by human activity in an early seral stage, e.g. by mowing, then succession will not progress.

Disturbed with Hammock - 740.1

These are areas that have been disturbed by human activities and on which the vegetation is dominated by tropical hardwood hammock, as described in a preceding narrative. The vegetation may either be a remnant of the vegetation that existed prior to the disturbance or has colonized the site after the disturbance. Examples of these areas are sites that have been partially or completely cleared and the vegetation is pioneering hammock, or hammock areas which have been extensively divided by roadways for a subdivision.

Disturbed hammocks, especially in the middle Keys, tend to be recolonized by Schinus. Some hammock areas on Vaca Key are now Schinus monocultures. Although Schinus occurs in the upper and lower Keys, disturbed hammocks, in these sub-regions, are more likely to succeed back to a hammock climax. The secondary succession is very much dependent upon the extent of the disturbance, the degree of disruption to the topsoil, and the proximity of the disturbed areas to sources of seed from either native or exotic species. Removal of litter and topsoil will result in a much longer recovery time and increase the potential for exotic invasion. Removal of both the vegetation and topsoil from hammocks generates conditions very similar to the effects of a severe fire in this forest type. According to Schomer and Drew (1982) who have reviewed the literature on fires in hammocks:

> ...[T]here is no firm estimate of how long a return time is required before the successional community converges upon the pre-burn hammock forest community. It appears, however, that several centuries may be required for the process of hammock generation to be

completed if it were initiated by a total obliteration of a pre-existing mature hammock stand. (emphasis added)

The impact of a disturbance within a hammock on its constituent fauna is also dependent upon the extent and severity of the disturbance. For instance, if an upper Keys hammock is disturbed in a manner which eliminates all of its torchwood (Amyris elemifera), the endangered Schaus swallowtail butterfly (Heraclides aristodemus ponceanus) will no longer have a host plant on this site and will undoubtedly leave the area. The Key Largo wood rat (Neotoma floridana smalli), listed as an endangered species, is reported to prefer mature, climax hammocks. Any disturbance which significantly degrades this type of forest will probably diminish its value as habitat for this rodent and possibly for the Key Largo cotton mouse (Peromyscus gossypinus allipaticola), another federally endangered species.

Assuming that invasive exotics do not dominate the succession, the early-recovery secondary seres will include a mixed association of pioneers. For high hammock, subsequent mid-recovery seral stages would probably include: willow bustic (Bumelia salicifolia), poisonwood (Metopium toxiferum), Jamaica dogwood (Piscidia piscipula), wild tamarind, (Lysiloma latisiliquum), mahogany (Swietenia mahagoni), wild lime (Zanthoxylum fagara), and gumbo limbo (Bursera simaruba). In low hammock, mid-succession would be characterized by: buttonwood (Conocarpus erectus), poisonwood, saffron plum (Bumelia celastrina), Spanish stopper (Eugenia foetida), black torch (Erithalis fruticosa), blackbead (Pithecellobium keyense), and seagrape (Coccoloba uvifera). In the absence of additional disturbances, the climax hardwood plant association would probably recover on the disturbed site in the several hundred year time frame cited earlier. If "seed trees" survived the original disturbance, less time would be required for recovery.

In the case of a cleared hammock wherein roadways or cleared areas are maintained as such, an "edge effect" at the boundary of the hammock and the clearing would result. The edge effect would persist as long as there is an opening in the hammock canopy large enough to increase light penetration to the lower stories. The edge plant community will be dominated by plants which require more light than is available below the closed hammock canopy. These plants are, in a real sense, holdovers from earlier seres, i.e. wild sage, fleabane, leadtree, etc. The edge of a hammock often provides habitat for Schinus and Australian pine, trees which do not mature within the deeply shaded hammock. Their presence represents a potential seed source for colonization of future disturbed portions of the hammock.

The extent of recolonization of a hammock by animals is very difficult to predict. If animals are driven out of hammock during the course of a disturbance, re-establishment of

pre-disturbance species populations will require a nearby source of colonizers as well as recovered habitat conducive to the successful re-settlement. In the cases of rare, threatened, and endangered species, breeding stock necessary to repopulate an area might not be available since the off-site population levels would be depressed throughout their range. (If they were abundant, they would not be listed as threatened or endangered.) Another potential problem for faunal recolonization is possible competition or predation by pet and feral animals or edificarian species, such as black rats (Rattus rattus), which might inhabit nearby areas which urbanized during the course of the recovery.

Bird populations would probably not reach pre-disturbance levels until nest trees available and food trees here bearing fruit or harboring prey insects. Birds would be especially vulnerable to predaceous pet and feral animals as well as to black rats.

Disturbed with Mangrove - 740.2

These are areas that have been disturbed by human activities and on which the vegetation is dominated by mangrove communities, as described in a previous narrative. The vegetation may be either a remnant of what existed prior to the disturbance or has recolonized the site after the disturbance. An example of such an area would be a mangrove area that was impounded by fill and cut off from tidal flow, and the mangroves have suffered a noticeable decline and loss of function.

Recovery of a tidal wetland system depends on the extent of damage inflicted upon historic water flows and tidal regimes. If only the mangroves themselves are damaged or removed, as in the case of moderate storm effects, there is an excellent chance that the system will recover in a relatively short period of time. If wetlands are filled and hydrologic conditions are significantly altered, then long term adverse impacts are to be expected. In some cases, the net result may be the creation of upland conditions which would obviously be inimical to the re-establishment of wetland associations.

Cleared and filled mangrove swamps, which are still subject to tidal inundation, will probably recover to a wetland sere, but mangroves might not recover their dominance. On filled land, an association of salt tolerant graminoids and/or shrubs, such as hurricane grass (Fimbristylis spathacea), dropseed (Sporobolus virginicus), sea daisy (Borrichia frutescens), saltbush (Baccharis halimifolia), etc., might form a persistent community. If normal tides do not regularly cover the site, then Schinus, Australian pine or leatherleaf could dominate and persist for long periods of time. Raising the level of a site or impeding tidal circulation makes it quite difficult for mangrove propagules to colonize an area because they are dispersed by moving seawater. Moreover, packed fill is very resistent to root penetration by mangroves.

In the case of impoundment, the resulting salt pond often suffers from extreme fluctuations in water depth, salinity, temperature and dissolved oxygen content. This results in a simplicifaction of the biota, often to the point where only the most tolerant forms survive. There are numerous examples throughout the Keys of impounded salt ponds containing the bleached remains of mangroves and only scattered and stunted black mangrove (Avicennia germinans) survivors. Needless to say, the faunal component of these systems is depauperate. A detailed description of salt ponds can be found in another narrative.

The secondary successional sequence of a 740.2 area is dependent upon the frequency and degree of tidal inundation. In the absence of tidal flow, a cleared and filled mangrove area will probably succeed through a pioneer sere dominated by salt tolerant forms, then move through a transitional stage, as described in the narrative for that community type. Once soils have built up and salts have been leached out by rainwater, the site will probably develop some type of hammock association. If the area is still subject to tidal inundation, then a filled mangrove area will probably develop as some type of wetland community with vestigial pockets of mangroves persisting. This prognosis assumes that invasive exotics do not dominate the succession, which is not the normal case in the Keys at present.

If the disturbance results in partial blockage of tidal flow and filling of a portion of the site, then a mosaic of community types could ultimately result. This appears to be the natural condition over much of the lower Keys where only slight differences in topography have resulted in the emergence of both upland and wetland communities co-existing in close proximity.

Recovery of most of the faunal elements of a disturbed mangrove association does not present the problems discussed for the rare community types. Sources for animal recolonization are abundant, in most cases, throughout the Keys. If there is any tidal flow into a mangrove area, eggs and larval forms of finfish and interverbrates will be carried into the site by these currents. A notable exception is that of the endangered American crocodile (Crocodylus acutus). Crocodiles are reported to nest in mangrove areas, in north Key Largo, in very small numbers. Preservation of a viable breeding population of these animals mitigates against disturbance of this breeding habitat. Recolonization by crocodiles of a recovered mangrove area, would depend upon the availability of breeding stock in a nearby area to migrate to the recovered site. Birds which utilize mangrove areas for nesting and/or feeding habitat, such as the threatened white-crowned pigeon (Columba leucocephala) and brown pelican (Pelecanus occidentalis carolinensis) would probably recolonize disturbed mangrove area only at the last stages of recovery.

Disturbed with Salt Marsh and Buttonwood -- 740.3

These are areas that have been disturbed by human activities and on which the vegetation is dominated by salt marsh and buttonwood associations, as described in a previous narrative. The vegetation may be either a remnant of what existed prior to the disturbance or has colonized the site after the disturbance. An example of such an area would be a wetland site that had been filled and recolonized by salt marsh or buttonwood associations.

Salt marsh and buttonwood associations are types of "transitional" communities and are described at length in the narrative entitled "Transitional Habitats." Both community types are normally found landward of the mangrove fringe or beach association and waterward of uplands which are not tidally inundated. Persistence of these transitional communities is dependent upon tide and saline soils by some authorities (Davis, 1942). The buttonwood complex is generally considered to be a seral stage of a successional sequence leading from a mangrove sere to an upland community tpe. The driving force behind this succession is the vertical movement of the substrate relative to the tidal influence. In the absence of disturbance, accumulating litter and soils raise the level of the land above the influence of normal tides to a height which favors the colonization and growth of bottunwood and its associated flora. Any increase in substrate height above mean sea level, which diminishes tidal circulation, also restricts the dispersal of mangrove propagules landward. Artificially raising the height of the substrate by filling accomplishes a similar effect.

The development of a salt marsh also reflects a diminution of tidal influence resulting from natural or man-made impoundment or substrate elevation. In the case of a salt marsh, edaphic conditions of saturated soils and hypersalinity favor dominance of highly salt tolerant graminoids and shrubs over that of mangrove and buttonwood. Buttonwoods appear to dominate in areas which contain soils which flush or drain on a regular basis and do not accumulate the salt loads that favor dominance of the salt marsh forms. Succession beyond the salt marsh generally requires some amelioration of these extreme edaphic factors. Once buttonwoods become established in a salt marsh, they tend to shade out the graminoids and shrubs.

There is a great deal of overlap in the species composition of mangrove, salt marsh and buttonwood associations. All three species of mangrove, buttonwood, salt grass (Distichilis spicata), dropseed (Sporobolus virginicus), Key grass (Monanthochloe littoralis), sea daisy (Borrichia fruchtescens), saltwort (Batis maritima) glasswort (Salicornia spp.), chestnut sedge (Fimbristylis castanea), and other salt tolerant forms can often be found growing is close association. It is the dominance of either the woody forms or the graminoids which stereotypes the community.

Areas of disturbance which are wetted by spring or storm tides, but do not contain poorly drained, saturated soils, are often vegetated by dense stands of small buttonwoods with an understory of sea daisy and salt tolerant graminoids. There appears to be severe competition between these trees for available nutrients and light so that individual trees remain small relative to the stature of "normal" buttonwoods growing in isolation. Succession, in these stands, requires accumulation of litter and soil in order for less salt tolerant forms to move in. These generally include: poisonwood (Metopium toxiferum), Jamaica dogwood (Piscidia piscipula), mahogany (Swietenia mahagoni), saffron plum (Bumelia celastrina), limber caper (Capparis flexuosa), blackbead (Pithecellobium keyense), black torch (Erithalis fruticosa), snowberry (Chiococca alba), and seagrape (Coccoloba uvifera). Once these species have colonized the site, the canopy and mid-story close up, diminishing light levels to the forest floor. This in turn shades out most of the lower story and ground cover graminoids, herbs and small shrubs. The number of buttonwoods significantly decreases with only a few of the hardy individuals remaining. This seral stage is known as the "thorn scrub" or low hammock sere.

The time frame for secondary succession in a site dominated by the salt marsh association is very much dependent upon a diminution of the extreme edaphic conditions which favor this community type. Undisturbed salt marshes probably persist, in an ecological sense, much longer than do buttonwood associations. Once succession begins, it is thought to move through a buttonwood sere and then through the thorn scrub to a climax hammock.

Disturbed areas which are only partially vegetated by buttonwood, but still contain open zones, are prime candidates for colonization by Schinus and Australian pine. Filled lands, which are slightly elevated above normal tides, support dense monocultures of these trees throughout the Keys. Thus, there is an abundant source of seed available for the colonization, by these invasives of freshly cleared and filled areas.

As was pointed out in the narrative describing transitional habitats, these areas normally contain a diverse fauna. Both salt marshes and flooded buttonwood zones are feeding habitat for numerous wading bird species. Reptiles and small mammals, such as the silver rice rat (Oryzomys argentatus), are very dependent upon transitional habitats. The suitability of disturbed transitional habitats for wildlife recolonization is dependent upon a number of factors including:

1. Diversity and structure of the emerging vegetation;

2. Nearby sources of breeding stock;

3. Proximity to urbanized areas;

4. Competition from feral, pet and edificarian species.

Disturbed with Exotics - 740.5

These are areas that have been disturbed by human activities where the vegetation is now dominated by exotic (i.e. non-native) plant species such as Australian pine (Casuarina equisetifolia) or Brazilian pepper (Schinus terebinthefolius).

Sites which are dominated by either of these two trees have undoubtedly lost all of their natural character and function. When dominant, they ultimately form monocultures because of the efficient modes of reproduction and ability to suppress germination of native species through allelopathic effects. They provide little in the way of food or habitat for native wildlife.

Schinus can reproduce in its own shade forming a dense stand with a closed canopy. Beneath this canopy is only leaf litter and young Schinus. Schinus can tolerate moderate saline influences and is often found intermingled with buttonwoods and mangroves. Australian pines are represented in South Florida by what are believed to be several species of Casuarina, although the taxonomy is not completely clear. Some forms reproduce through bird and wind dispersal, whereas other reproduce vegetatively by root suckers. They form dense, monocultural stands with closed canopies and are salt tolerant.

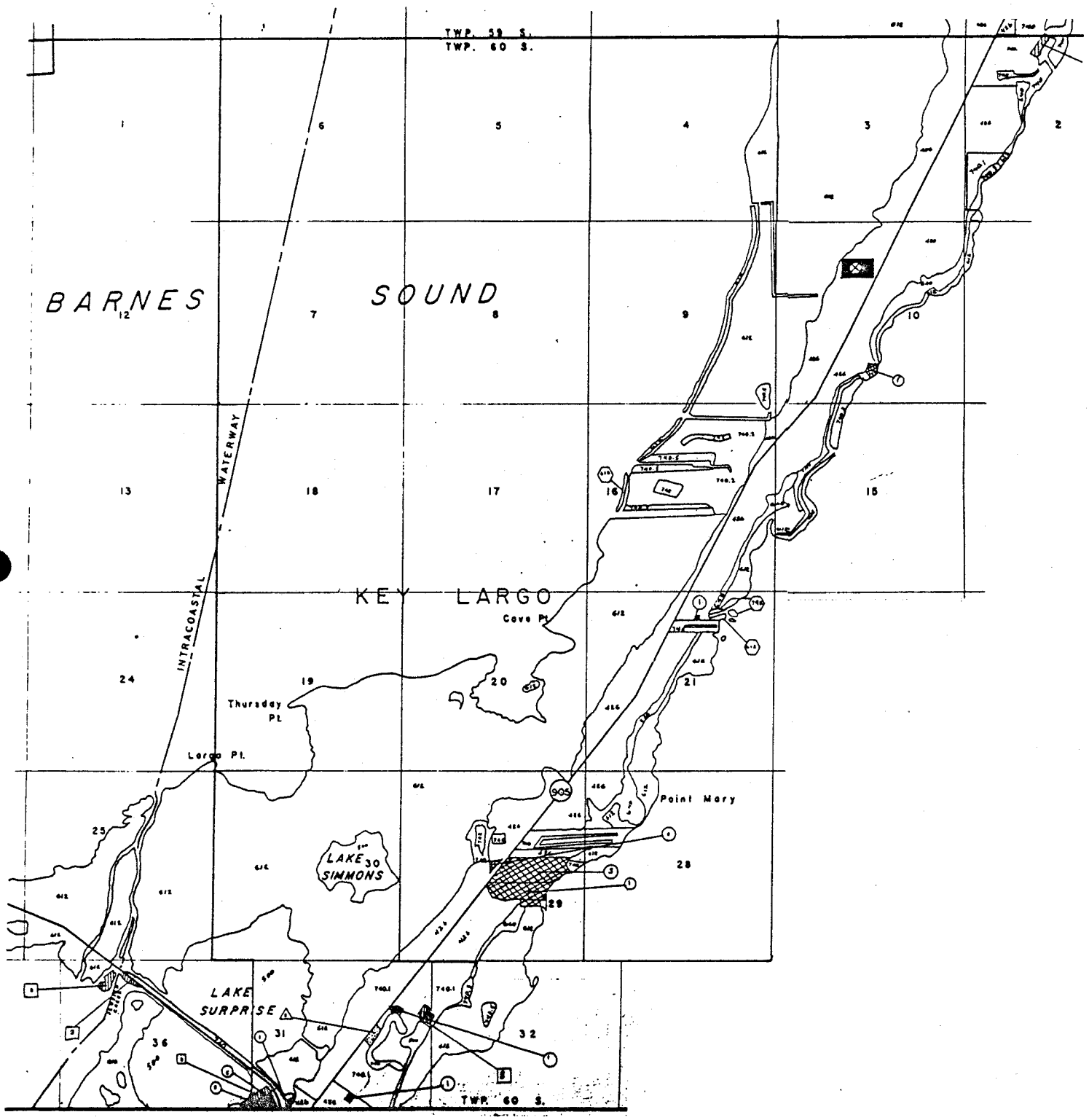
The successional future of these forests is unknown since they have not been in South Florida for very long. It is quite possible that these trees will be considered as "exotic sub-climaxes" which will persist for long periods of time. Restoration of a natural community on one of these sites would require:

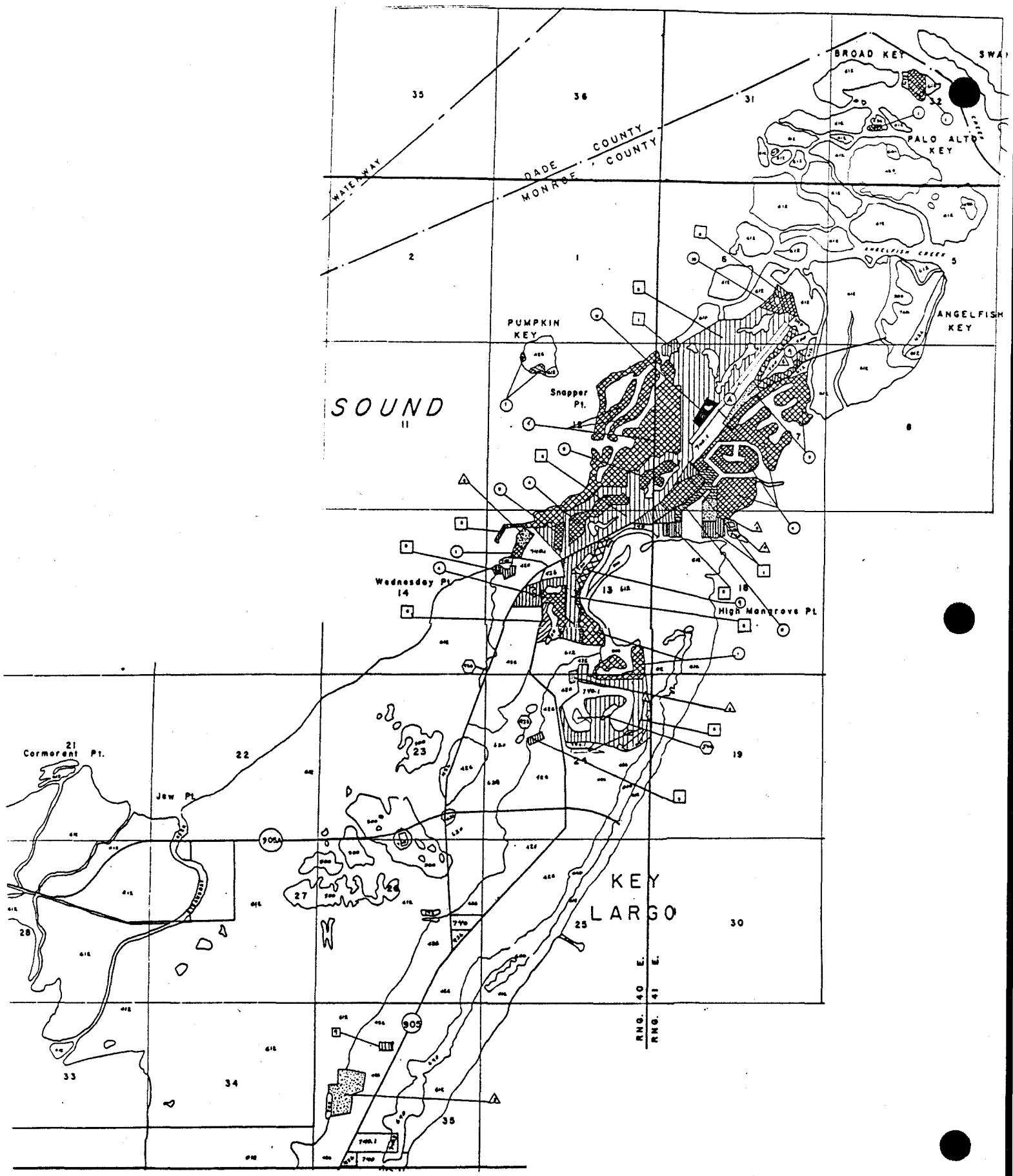
1. Total removal of all exotics;
2. Total removal of leaf litter and seeds;
3. Possible replacement of surface soils;
4. Frequent and regular removal of exotic sprouts;
5. Planting with native species of shrubs and trees.

These are areas that have been disturbed by human activities (e.g. partial or complete land clearing) where the vegetation is dominated by slash pineland species. The vegetation may be either a remnant of what existed prior to the disturbance, or has colonized the site after the disturbance.

Natural disturbance in the form of fire is an integral part of the ecology of a South Florida pinewoods. Fire retards hardwood succession and may eliminate some exotic invaders. Most

natural fires occur during the wet season, at which time the soils are moist and the air is humid. If fire occurs regularly, and litter does not build up into large fuel stores, these wet season fires do not reach up into the crowns of the pines and destroy them, nor do they seriously damage other fire-adapted vegetation. Wildlife can easily escape these ground fires by moving off-site or burrowing beneath the ground.


TWP. 59 S.
TWP. 60 S.
BARNES SOUND
INTRACOASTAL WATERWAY
KEY LARGO
Cove Pt.
Thursday Pt.
Largo Pt.
Point Mary
LAKE SIMMONS
LAKE SURPRISE
905
TWP. 60 S.


BROAD KEY
PALO ALTO KEY
DADE COUNTY
MONROE COUNTY
WATERWAY
ANGELFISH CREEK
ANGELFISH KEY
PUMPKIN KEY
Snapper Pt.
SOUND
Wednesday Pt
High Mangrove Pt
Cormorant Pt.
Jew Pt
KEY LARGO
RNG. 40 E.
RNG. 41 E.
905A
905

8.
FRESHWATER WETLANDS

Small expanses of freshwater wetlands occur, primarily in the Lower Keys, as vestiges of the more expansive systems that existed prior to the 1950's. The diminution of these wetlands has resulted from filling for development and draining for mosquito control.

Biota

Both Cowardin (1979) and Clark (1977) characterize freshwater wetlands by the presence of erect, graminoid vegetation rooted in poorly drained, saturated soils that are rich in organics. Wetlands are flooded either permanently or for a sufficient period each year to support communities of water dependent plants. Two types of freshwater wetlands occur in the Keys. The most extensive is the Sawgrass (Cladium jamaicense) - dominated marsh. Keys sawgrass marshes are quite different from the vast sawgrass marshes of the Everglades where a tall (6-10 foot) dense monoculture of sawgrass occurs on deep (2 feet) peaty soils that are covered by water for most of the year. In the Keys, small, disjunct sawgrass-dominated associations occur on much shallower soils, and individual plants are much smaller. Other species common to Keys' sawgrass marshes include: Saw Sedge (Cyperus ligularis), White-top Sedge (Dichromena floridensis), Leather Fern (Acrostichum sp.), False Foxglove (Agalinis spp.), Aster (Aster tenuifolius), Broom Sedge (Andropogon glomeratus) and Buttonwood (Concocarpus erectus). Two vines, Mangrove Rubber Vine (Rhabdadenia biflora) and Wild Allamanda (Urechites lutea), as well as a variety of bromeliads, occasionally occur on the Buttonwoods.

Sawgrass occurs ubiquitously in both fresh and brackish wetlands. In areas that contain brackish water or slightly saline soils, the association often includes other salt tolerant forms including Eleocharis cellulosa, the sedges Fimbristylis castanea and F. spathacea, and the grasses Sporobolus virginicus and S. domingensis. In these areas, Buttonwood and mangroves also frequently occur.

Freshwater marshes normally support a highly diverse and abundant fauna that includes fish, invertebrates, amphibians, reptiles, birds and mammals. These marshes are know to be critical to the reproductive success of animal populations that bear young during the dry season.

Freshwater marshes are important to both resident and migratory bird populations. During the dry season, freshwater wetlands are the only natural sources of water for all of these wildlife forms.

Disturbances

As with other Keys' habitats, the impact of hurricanes on freshwater wetlands can be devastating. In addition to the outright destruction of the system's biota, the deposition of salt water can have an indirect adverse effect on its flora. Hurricane impact is discussed more fully in the section dealing with tropical hardwood hammocks.

Human impacts that most significantly affect freshwater wetlands include filling, mosquito ditching, and the dredging of upland canals and borrow pits. While filling directly eliminates this habitat, dredging is believed to diminish surface freshwater resources. The blasting and dredging that accompanies canal and borrow pit construction exposes shallow, water-containing strata of bedrock to salt water intrusion and evaporation. This lowers freshwater levels in ponds and marshes, thereby decreasing the size of this habitat and diminishing, or making unpalatable, drinking water supplies available for wildlife.

Mosquito ditches, have had disastrous consequences for freshwater wetlands. The ditches were intended to drain or bring tidewater to upland areas that contained standing water, which were believed to be mosquito breeding areas. As a consequence, numerous freshwater wetlands were drained or subjected to salt-water intrusion, thereby creating a brackish mixture in what was historically a freshwater habitat. Ultimately, salt tolerant vegetation displaced freshwater-dependent species and much fresh-water wildlife habitat was lost. Ironically, many of these ditches, since they are not maintained, have become cut off from surface tidal influence, and therefore contain freshwater during the wet season - the period of maximum mosquito activity. These ditches also tend to trap deer fawns. The ditches do, however, provide limited habitat for Cattails and Leather Fern as well as alligators and small fish. Because freshwater wetlands are centers of wildlife activity human settlement adjacent to these areas, with its accompanying vehicles, domestic pets, etc., may significantly impact the fauna even if the wetland itself is undisturbed.

9.
NEARSHORE WATERS

The waters surrounding the Florida Keys consist of flats, channels, sounds, cuts and open waters, as well a series of man-made features including channels and canals. These waters constitute a vital resource upon which the natural and built environment and the economy of the Florida Keys depend. Water quality is generally very high and the State of Florida recently designated all non-manmade nearshore areas in the Keys as "Outstanding Florida Waters." In comparison to other areas in the State of Florida, Florida Keys' waters are very low in pollutants and contaminants, and violations of state water quality standards are observed only on very rare occasions at water

quality monitoring stations in the Keys. Water quality data are not complete, however, and given the dynamic nature of growth and development in the Florida Keys it is difficult to say whether continued high quality can be maintained with the additional discharges that will accompany new growth and development.

Water quality in open, natural waters reveals little if any adverse effects from the development in the Florida Keys. In fact, water quality monitoring stations near the Key Colony Beach wastewater treatment plant show no demonstrable degradation of water quality. In some of these man-made canals water quality is demonstrably degraded with depressed dissolved oxygen and abiotic conditions. In part, water quality in canals is affected by surface water run-off and wastewater effluent, however, significant degradation has been observed in canals where no structures have ever been developed. The principal causes for such degradation are excessive depths, intrusion into aquifer waters containing high levels of hydrogen sulfide, dead-end configurations that accumulate sea grasses and poor flushing. Periodic algae blooms and occasional fish kills indicate conditions that are possibly remedial through hydrographic modifications or other mitigation strategies. In addition, dredge and fill activity itself, involving excavation and the suspension of material in the water column, have temporary, if not long-term, impacts on water quality. The laws regarding dredge and fill activities have been significantly changed and it is assumed that the Department of Environmental Regulation and the Army Corps of Engineers, the agencies with jurisdiction over dredge and fill permits, will not issue any further permits that would have a demonstrable adverse impact on nearshore water quality.

A review of the Department of Environmental Regulation's (DER) report on the Proposed Designation of the Waters of the Florida Keys as Outstanding Florida Waters indicates that water quality in canals as surveyed by the Environmental Protection Agency (EPA) is as follows:

1. Dissolved oxygen violations [of DER's standards] are common in most canals particularly at depths of greater than 4 to 6 feet;

2. Dissolved oxygen decreases landward of the mouth of the canal;

3. Septic tank leakage has not been demonstrated to move rapidly into canals however, evidence of long term loadings suggests that septic tank effluents ultimately do reach canal waters;

4. Heavy metal contaminants are not found in canals;

5. Fecal coliforms in canals do not generally violate federal and state standards; and

6. Marine grasses and algae carried into canals by winds or tides do result in elevated Biological Oxygen Demand (BOD) which often result in depressed dissolved oxygen conditions.

Available data do not conform to the general experience and expectation that septic tank effluent will rapidly migrate to and contaminate adjacent surface waters. In 1979, CH_2M Hill, an environmental consulting firm, conducted dye tracer studies of septic tank leachate and was unable to demonstrate significant horizontal migration of effluent. Nor do the available data confirm the suspected degradation of nearshore waters by point source discharges from sewage treatment plants. Indeed the available data suggests that existing levels of treatment are adequate to protect receiving water quality. According to DER, 99% of the treatment plants in the Florida Keys meet standards for secondary treatment and monitoring at or near discharge points indicates that there has been "minimal water quality degradation." Preliminary data from the Department of Environmental Regulations 205(j) study indicate that water quality is generally not degraded except for direct discharges from live-aboard vessels and discharges from seafood processing plants, and that pollution concentrations are significantly diluted by ambient waters as a result of tidal interchange. The DER report for the OFW designation summarizes known water quality data as follows:

1. Special studies done by various consultants, the state and EPA have demonstrated that canal construction severely affects water quality, especially dissolved oxygen.

2. Point source discharges have not been shown to be a major problem. However, trend data may show subtle effects when sampled for long periods.

3. Sources such as septic tanks and boreholes may significantly affect water quality. This is the subject of the current "205(j)" study.

4. Some studies of construction projects, such as the bridge replacement program, have not documented any post-construction water quality problems.

5. Several studies have pointed to a need for centralized wastewater treatment.

6. When completed in 1985, the present "205(j)" study is expected to evaluate the severity of water quality impacts from point and non-point sources.

7. The available water quality data show few violations of water quality standards. However, the coral reef and mangrove communities probably

require stringent controls on pollution sources. Subtle changes in coral rings (similar to tree rings) may reflect changes in water temperature that are difficult to measure. Although large masses of water such as the Gulf Stream and Florida Current provide a buffer against rapid change by man, the long term effects of road and other construction, boating and recreation, and sewage disposal require more study.

The absence of deteriorated water quality, however, should not be taken as an indication that water quality in nearshore waters will not deteriorate as a result of future development and the well-documented experience of other communities where intense development has taken place indicates that Monroe County and the Department of Environmental Regulation must carefully and discretely monitor receiving bodies of water so as to determine whether future growth and development will result in nutrient loadings in nearshore bodies of water that exceeds the assimilative and dilutive capacity of those bodies. In particular, the County and DER must monitor the cumulative effects of discharges from sewage treatment plants and the impact of the installation of septic tanks in the vicinity of canals and natural water bodies. The absence of deteriorated water quality conditions in existing canals and other receiving bodies of water may simply be a reflection that only a small portion of available lots have been developed and therefore that the available volume of water is sufficient to dilute the loadings created by those limited number of units. Given the existing wide array of subdivision intensities, in terms of what percentage of lots developed, current indications are that septic tank installations that are properly installed and maintained in accordance with Chapter 10(d)(6) the Florida Administrative Code are effective in protecting nearshore water quality from degradation through careful monitoring is needed because of known contamination in several subdivisions. It is important to understand that traditional analysis of septic tanks used around the country must be carefully translated when applied to the Florida Keys because of the unique character of the substrate. The Key Largo limestone formation which underlies the Keys north of the Seven Mile Bridge is extremely porous and water movement through the limestone is rapid. It would be appropriate for studies to be conducted in that area to determine the migratory pattern of septic tank discharges and the speed with which those discharges are reaching surface bodies of water. Similar studies have been conducted in many parts of the country including barrier islands in South Florida, and the information produced by such a study would be extremely important in evaluating or predicting the cumulative impact of continued growth and development which would be dependent upon individual wastewater treatment facilities for wastewater treatment. Another area of care that must be observed in translating the experience and knowledge of the Mainland with septic tanks and treatment plants to the Florida Keys is the oceanic nature of the Florida Keys which results in a receiving

body of water of practically infinite volume. The dilutive capacity however, is dependent upon water movement rates and therefore tidal flushing. This dilutive capacity is markedly different than the characteristics of an inland lake, freshwater stream or estuarine system like that found in many of the studies that have been undertaken around the country.

10.
EVALUATION AND RANKING OF THE IMPACT POTENTIALS AND IMPACT SENSITIVITIES OF FLORIDA KEYS HABITATS

Two matrices were developed for the Monroe County Comprehensive Plan to evaluate the impacts or potential impacts on the 10 major habitat types identified in the Florida Keys. The first (Table 1) is an impact matrix that quantifies the impact of activities within and adjacent to a habitat type on its structure and function. The second matrix (Table 2) is a sensitivity matrix that relates habitat type to an evaluation of the potential for such impacts.

Matrix of Impacts on Habitat Structure and Function

While all habitat types are adversely affected by human development and activities, the extent of environmental damage is a function of the nature of the impact and the habitat type. Thus a valuation system was developed to facilitate a comparison between the various habitats by their degree of sensitivity to environmental degradation. It must be stated at the outset that the values assigned reflect the collective "best guess" of specialists. While such an eclectic approach probably precludes complete objectivity, it nonetheless represents the most productive approach to assessing the nature of the probable interfaces between human impacts and habitat types in the absence of extensive field studies. Activities deemed important to these systems were listed and numerical ratings were assigned as follows: 4 = very high impacts, 3 = high impacts, 2 = moderate impacts, 1 = low impacts, 0 = not applicable. A general discussion of each activity or impact is presented as is a discussion of individual impacts in each habitat type.

Impact Activities in Florida Keys Habitats

Dredging. Dredging activities produce significant impacts on all habitat types. In the Keys most of the habitats are very fragile and any significant dredging produces effects that are usually deleterious and difficult to reverse. The mechanism whereby dredging precipitates environmental damage is the lowering of the level of the groundwater table. This in turn modifies the microclimatic framework within which the processes of natural selection generate the vegetation assemblages that constitute the trophic base of all ecosystems. Consequently, all trophic levels are at least indirectly affected. Unquestionably, such damage will be most severe when it occurs within, as opposed to adjacent

to, a habitat. The continuity of the groundwater table underlying contiguous systems dictates that dredging in one habitat type may result in indirect damage to adjacent types.

Filling. The introduction of fill into any habitat degrades its integrity in two basic ways. First, the deposition of soil directly eliminates underlying vegetation. Secondly, the fill becomes the rooting stratum which, unlike the native topsoil, is not an orderly structured system in balance with native vegetation but rather a structurally heterogeneous medium that is unsuitable for successional recovery, and instead promotes colonization by invasive exotics like Brazilian pepper. Such colonization generally precludes subsequent recovery.

Impoundment. Impounding water in upland ecosystems modifies their existing soil moisture regimes and selects for a more water-tolerant flora. This in turn generates an altered faunal assemblage. Further, impoundments represent an inducement to colonization or use by animals to whom open water is a critical element of the niche. These changes in habitat character ultimately reduce the extent of native habitat coverage and destabilizes their natural function. Generally, the activity does not affect freshwater wetlands and salt ponds to any significant degree and may help maintain fresh water lenses in freshwater wetland areas. Impounding of salt ponds with too much freshwater could result in the dilution of highly saline conditions in these areas, with resulting succession to more freshwater communities.

Mosquito Ditching. Mosquito ditching has occurred over many years in the Keys. Construction of these ditches is generally intended to drain the standing water off areas with some tidal flushing to eliminate mosquito habitat and to provide avenues for fishes to invade areas where mosquito larvae can be consumed, thus reducing mosquito populations. In areas which receive little tidal flow, ditching usually results in very significant impacts through the introduction of saltwater to these systems. Also, exotic plant species often colonize the mosquito ditch spoil areas. Some impacts may also occur to adjacent areas which are either drained by the ditches or subterranean saltwater wedges replace freshwater lenses.

Mosquito Spraying. Mosquito spraying activities in pinelands and freshwater wetlands result in high impacts for these sites. In the case of pinelands, mosquito spraying with insecticides reduces populations of insect pollinators which are responsible for maintaining the plant species in these areas. Spraying also results in more serious impacts in freshwater wetlands by disruption of the food web in these systems. Impacts are generally less in the transitional areas.

Road Construction. Road construction involves both the movement of dirt and filling operations in all habitats. Associated grading and ditching operations may result in either impoundment of drainage which can substantially impact habitats.

Road construction results in the removal of the existing vegetation and, where deposition or grading occurs, promotes invasion by exotic species. These activities can be especially devastating to hammocks because any opening of the habitat upsets the delicate micro-climatological regime and leads to the general demise of the system.

Road construction activities in mangrove areas generally cause changes in grade or elevation, which modifies the intertidal regime and ultimately selects for different habitat types. But in all habitats, the aforementioned consequences of road construction diminish their real extent, retard or thwart successional recovery and diminish natural functions.

Utilities. Utility construction generally results in few impacts in wetland areas. Some clearing may be necessary for the initial right-of-way construction, but the plant dominants in both fresh and saltwater wetlands are usually not tall enough to interfere with powerlines. Digging and refilling for underground utilities should result in little long-term impacts if elevations are restored to preconstruction levels.

In pinelands and hammocks, utility construction results in severe impacts due to removal of the canopy trees to prevent interference with powerlines and root growth over pipelines. Because utility lines generally follow roadways, their environmental impact is often a secondary consequence of road construction. The impact of such a joint venture is enumerated on Table A under the category of road construction. On the other hand, the numerical rankings for the impact of utilities assumes right-of-way clearing and maintenance independent of road construction.

Land Clearing. Land clearing in any type of habitat causes immediate destruction of its flora and habitat for its fauna. In many cases, several decades are required for reestablishment of the original habitat, since its successional sequence is long. The clearing of pines and hammocks is likely to promote an invasion by exotics that would preclude revegetation by many endemic species.

Land clearing in adjacent sites generally has little impact on the habitats in surrounding areas; however, the overstory of fragile beaches and berms and hammocks may be significantly affected by microclimatic changes in adjacent areas.

Sewage Disposal. In general, Florida Department of Environmental Regulation permitted sewage effluent disposal would have little effect on the flora of wetland areas except for salt ponds where the fragile balance of hypersaline conditions can be upset by the introduction of freshwater from sewage disposal. This activity can result in decreased salinity. Impacts would also be severe in areas such as hammocks and possibly pinelands, where increased freshwater modifies the soil moisture regimes and promotes succession to a wetter habitat, such as a freshwater marsh.

Sewage disposal in adjacent areas generally would have little impact on any of the communities or habitat types found in the Florida Keys.

Landfill Operations. Landfill operations in any habitat results in the obliteration of existing communities and generally in higher elevations. In wetland areas, such activities can transform the native system into upland habitats. In the Keys, disposal is generally by landfill build up with some material placement over the site. If allowed to revegetate naturally, these areas would generally succeed to upland communities; however, the invasion of exotics is often significant and commonly upsets the normal successional regime, perhaps irreversibly.

Any environmental degradation resulting from disposal in adjacent areas would be attributable to increased surficial runoff. Such impacts would likely be minor except to mangroves or open water systems where water quality could be adversely affected.

Debris-Solid Waste Disposal. In many parts of the Keys large quantities of debris have been left by haphazard disposal operations which continue to this day. Such disposal results in an increased amount of combustible materials and this increases fire hazards especially in drier upland habitats.

In the case of freshwater wetlands and salt ponds, such disposal operations could have a significant impact by altering biogeochemical cycling rates. Also, disposal operations in many of the habitat types could open up the canopy or cover the existing vegetation and introduce propagules of exotic species which often outcompete endemic plants on disturbed sites.

Consumptive Water Use - Domestic. Domestic consumption of water entails the withdrawal from the freshwater lens that underlies most of the archipelago islands. In many parts of the Keys, habitats should generally incur (such as pinelands) where a specific groundwater regime is crucial for normal successional change. Removal of freshwater for septic tank systems produces little net change in water balance since the water usually is returned to groundwater.

The impact of consumptive use of water in adjacent areas would probably be low for most habitats, however, if very small freshwater systems are impacted, animals in adjacent areas may be deprived of water sources. For example, many animals such as the Key Deer may travel fairly long distances to a particular freshwater source. Moderate impacts could generally be expected from activities that result in a net transfer of water to habitats that could suffer from higher water tables.

In areas where individuals withdraw water from the pipeline and subsequently dispose of it in septic tanks, the impacts could be more significant especially in drier habitats such as pinelands and hammocks.

Consumptive Water Use - Commercial. Any significant amount of water withdrawn from a freshwater lens on a commercial basis could severely impact these areas, whether the water is taken from within the site or from adjacent sites. In feature substrate such as the Key's limestone, this freshwater lens is not an isolated entity but rather one portion of an interconnected water resource system that also includes surficial water in sinkholes and any freshwater wetlands. Diminution of a lens can increase the percolative loss from such sources, and thereby cause freshwater wetlands and soil moisture regimes in all upland systems to become drier. This in turn results in altered selection pressures and ultimately in modified biotic assemblages. Further, substantial withdrawal (as is presently occurring for irrigation of commercial coconut nurseries) invites saltwater intrusion whose environmentally degrading effects are well-documented.

In adjacent areas, the impacts of consumptive use of water would probably be lower; however, if very small freshwater systems are lost, animals in adjacent areas could be deprived of water sources.

Settlement. Human settlements generally involve both the direct loss of habitat and the introduction of people and pets to these sites. Habitat loss is generally severe since structures result in permanent or long-term loss. Settlement in adjacent areas may result in significant impact due to the introduction of exotic plants, domestic pets, especially dogs, which can severely impact populations of deer, rabbits and other species.

Vehicular Traffic (On Road). On-road vehicular traffic promotes increased interaction of both people and automobiles with animal species. Significant impacts would result from vehicular traffic through pinelands, for instance, where species such as the endangered Key Deer may be reduced both within its habitat range and adjacent areas. And while the loss of this and other END/THR/SCC species is particularly significant, the general attrition of all mobile forms that results from vehicular traffic represents a significant loss of the limited pool of genetic variability that characterizes small insular populations.

Recreation. Environmental degradation attributable to human recreational pursuits result both from habitat loss and increased interaction with wildlife. For instance, any recreational use of natural areas, including hiking, all-terrain vehicles, and plant collecting, can denude those sites, thereby reducing plant populations, wildlife habitat availability, and successional recovery potentials. The concomitant contact with wildlife resulting from such activities has the general effect of reducing the desirability to wildlife of utilizing these interface sites, reducing the extent of suitable habitat and ultimately population levels.

Toxic Wastes. Toxic waste disposal in areas such as freshwater wetlands, salt ponds and beaches and berms could be very significant due to the small amount of these habitats which exists on the Keys. Also any toxic waste introduced into freshwater wetlands, the source of drinking water for many endangered species, would be damaging.

In general, toxic waste disposal in nearby areas would result in minimal impacts unless some import of the toxic waste occurred through overland flow or other means. Such natural transfer of upland habitats, for instance, could endanger habitats of relatively low elevations, such as freshwater wetlands and salt ponds.

B.
THE BUILT ENVIRONMENT

1.
EXISTING USES

The majority of North Key Largo is undeveloped, with the exception of the Ocean Reef Club. Much of the currently undeveloped land is owned by State and federal agencies. There are three Developments of Regional Impact (DRI's) in the area (see Table below). Port Bougainville/Garden Cove has been approved for 2806 units, 600 of which are planned as hotel rooms. The project is currently in receivership, and the plans may be modified on the basis of the current economic climate in the area. The Ocean Reef Club has 1800 existing units, and plans for approximately 400 more.

Their are six subdivisions in the area (see Table below) with 425 total lots, each of which is at least partially built out.

SUBDIVISIONS IN NORTH KEY LARGO

SUBDIVISIONS	Units/Lots	Acres
Knowlson Colony	67	21.80
Gulfstream Shores	100	25.72
Ocean Reef Shores	180	24.76
J.H.T. Subdivision	20	7.80
Post/Nichols Subdivision (2 units built)	22	7.90
Madeira Village	36	20.64
TOTAL	425	108.62

OTHER VESTED PROJECTS

	Units/Lots	Acres
Port Bougainville (600 hotel rooms)	2806	218.80
Garden Cove	220	41.70
Ocean Reef Club (1800 units built)	2200	1100.00
Angler's Club	100	43.38
TOTAL	5226	1403.88

OTHER PROJECTS OF INTEREST

	Units/Lots	Acres
Carysfort	512	107.2
Largo Beach and Tennis Club	224	22.5

2.
TRANSPORTATION

a.
ROADS

Introduction

A review of U.S.1 and the County's secondary road system shows the following:

U.S. 1 in Monroe County carries its highest traffic volumes during February, March and April, both weekdays and weekends, with traffic volumes decreasing during the rest of the year for weekdays. Weekends and other holiday periods have traffic levels matching "season" weekday levels, at least from data for the Northern Keys.

Peak periods traffic based on North Keys surveys occurs during both weekday and weekend afternoons, not during morning or evening rush hours.

Overall accident levels closely correspond to the times, dates, and places of traffic congestion.

Through traffic at the northern limits of U.S. 1 in the County has shown a 3-4% annual traffic increase for 1978-84.

Traffic in communities like Key Largo, is showing 5-10% annual increase. Thus, local travel, not through traffic, may be the greatest source of traffic congestion on U.S. 1. This traffic growth could congest more miles of U.S. 1 in the near future.

A detailed analysis of County Road 905 from the U.S. Route 1 intersection to Card Sound Road in North Key Largo was conducted by Barton-Aschman Associates. The purpose of the analysis was to determine the existing and projected traffic conditions on North Key Largo. Their study procedures included the following tasks:

-- Daily traffic counts were conducted in March, 1985 on County Road 905 and Card Sound Road to identify existing peak season traffic volumes and travel patterns.

-- Existing travel patterns were evaluated to determine the volume of traffic passing through the area as well as the number of vehicles generated by the Ocean Reef Club.

-- Future Traffic projections were prepared for possible development scenarios selected by Siemon, Larsen & Purdy.

-- The resulting traffic conditions on CR 905 were evaluated to determine projected levels of service and roadway improvement needs.

Existing Roadway Conditions

County Road 905 functions as an extension of U.S. Route 1 to North Key Largo and to Card Sound Road. It operates with one lane in each direction, but separates at the intersection with Card Sound Road into a pair of one-way streets. The alignment of the roadway and the boundaries of our study area are shown on Figure 1. The only major development located in the study area is the Ocean Reef Club located at the north tip of North Key Largo. The private club is a self-contained destination resort which includes residential, entertainment, and commercial facilities.

The daily traffic counts on County Road 905 and Card Sound Road indicate that the highest one hour of traffic during the day represents approximately 8 percent of the daily traffic. With this peak-hour percentage, the design capacity of the two-lane roadway at Level of Service C is 15,125 vehicles per day. This capacity was calculated using Urban Transportation Planning (UTP) Procedure No. T1 assuming an 8 percent peak-hour factor. At Level of Service D conditions, the daily capacity of the two-lane roadway would increase to 18,250 vehicles.

The March 1985 traffic counts on County Road 905 and Card Sound Road are shown on Figure 2. These volumes which range from 2084 vehicles near U.S. 1 to 3124 vehicles north of Card Sound Road represent from 14% to 21% of the design capacity of the roadway. These volumes represent Level of Service A conditions.

An analysis of the existing daily volumes was performed to identify several key transportation characteristics, including the amount of through traffic using CR 905 and the daily traffic generating characteristics of this Ocean Reef Club. The results indicate that approximately 70 percent of the traffic currently using the roadway are destined to or from the Ocean Reef Club. The remaining 30 percent are through trips with neither an origin nor a destination in the study area. This finding is significant because it indicates that through traffic is not a major component of traffic using the roadway and that future traffic conditions will largely be dictated by the development program in the study area.

STUDY AREA LOCATION MAP

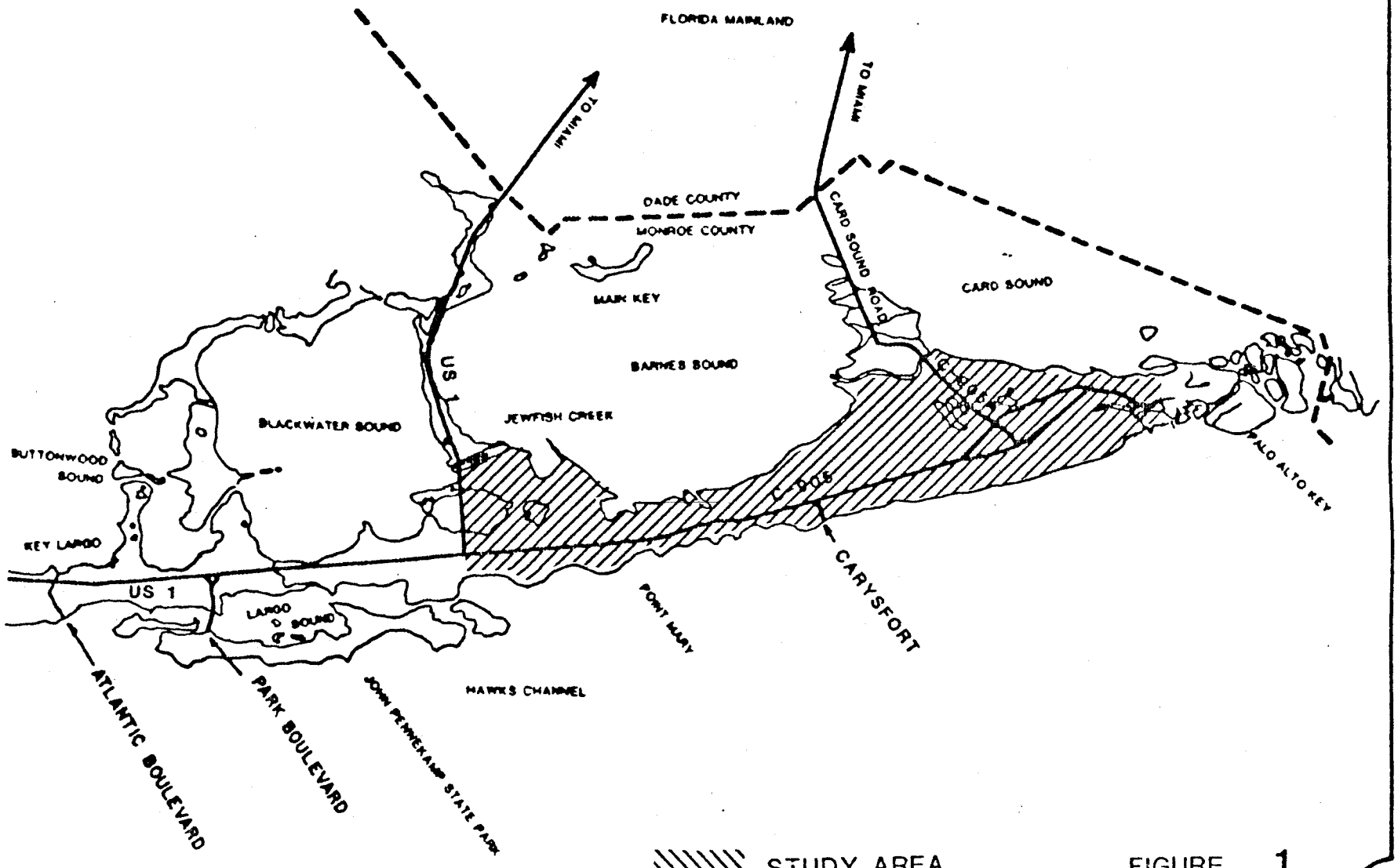


FIGURE 1

ADJUSTED AVERAGE DAILY TRAFFIC

EXISTING VOLUMES

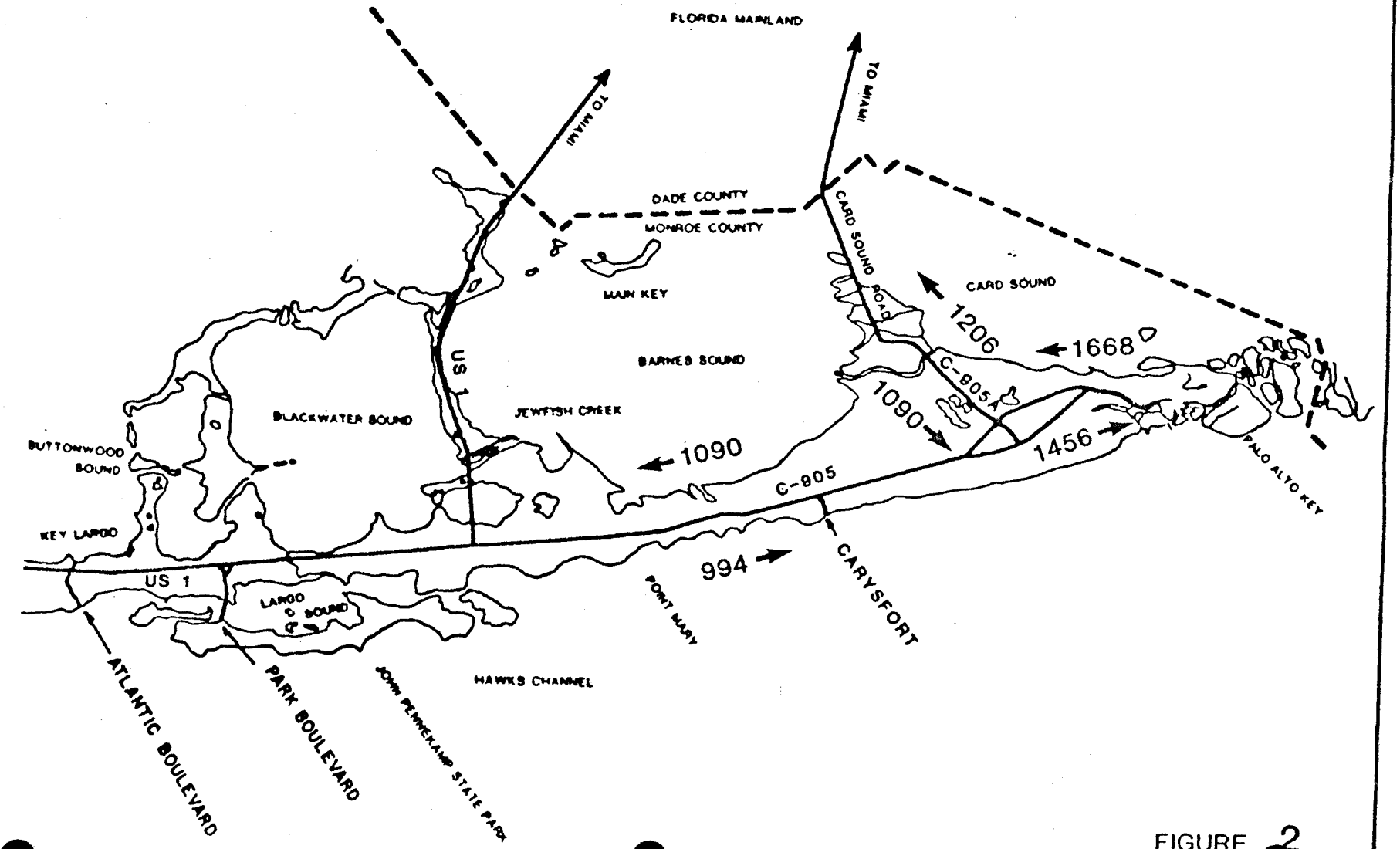


FIGURE 2

The Ocean Reef Club generated a two-way total of 3124 vehicle trips on Friday and 2315 Trips on Saturday. Based upon 1400 residential units, the volumes represent 2.23 and 1.65 daily trips per unit respectively. The weekday trip generation rate is approximately 30 percent below the standard rates identified in the ITE Trip Generation Manual for recreational homes (Code 260). These rates are assumed to be representative of the traffic generating characteristics of similar developments which could be constructed in the study area.

Projected Roadway Conditions

Future traffic volumes on CR 905 were estimated by applying trip generation rates to the alternate development scenarios and assigning the trips according to a distribution pattern. Also a growth rate of 10 percent per year was applied to the through traffic using CR 905 between U.S. Route 1 and Card Sound Road. The study area was divided into five development zones as shown on Figure 3. The traffic generation resulting from each development scenario was calculated by zone and then assigned according to a specific distribution pattern for each zone. The resulting traffic volumes were then compared to the design capacity of the roadway to determine expected roadway conditions.

The development scenarios were chosen to illustrate the expected plan alternatives of no further development (Scenario 1) scattered development (Scenario 3), and clustered development (Scenario 4).

Development Scenario 1

-- No additional development occurs in North Key Largo

Table 1

Development Scenario 1 - Projected Volumes and Conditions

Zone	Projected Daily Traffic Volume	Existing Design Capacity	Volume/ Capacity Ratio	Level of Service
A	3285	15125	0.22	A
B	3285	15125	0.22	A
C	3285	15125	0.22	A
D	3285	15125	0.22	A
E	3125	15125	0.21	A

Without additional development, the only increase in traffic that can occur will be due to growth in through-traffic. This growth has been estimated at approximately 10 percent per year or 1200 vehicles in 20 years. The traffic volumes willl remain low and the roadway will provide a high level of service.

DEVELOPMENT ZONE MAP

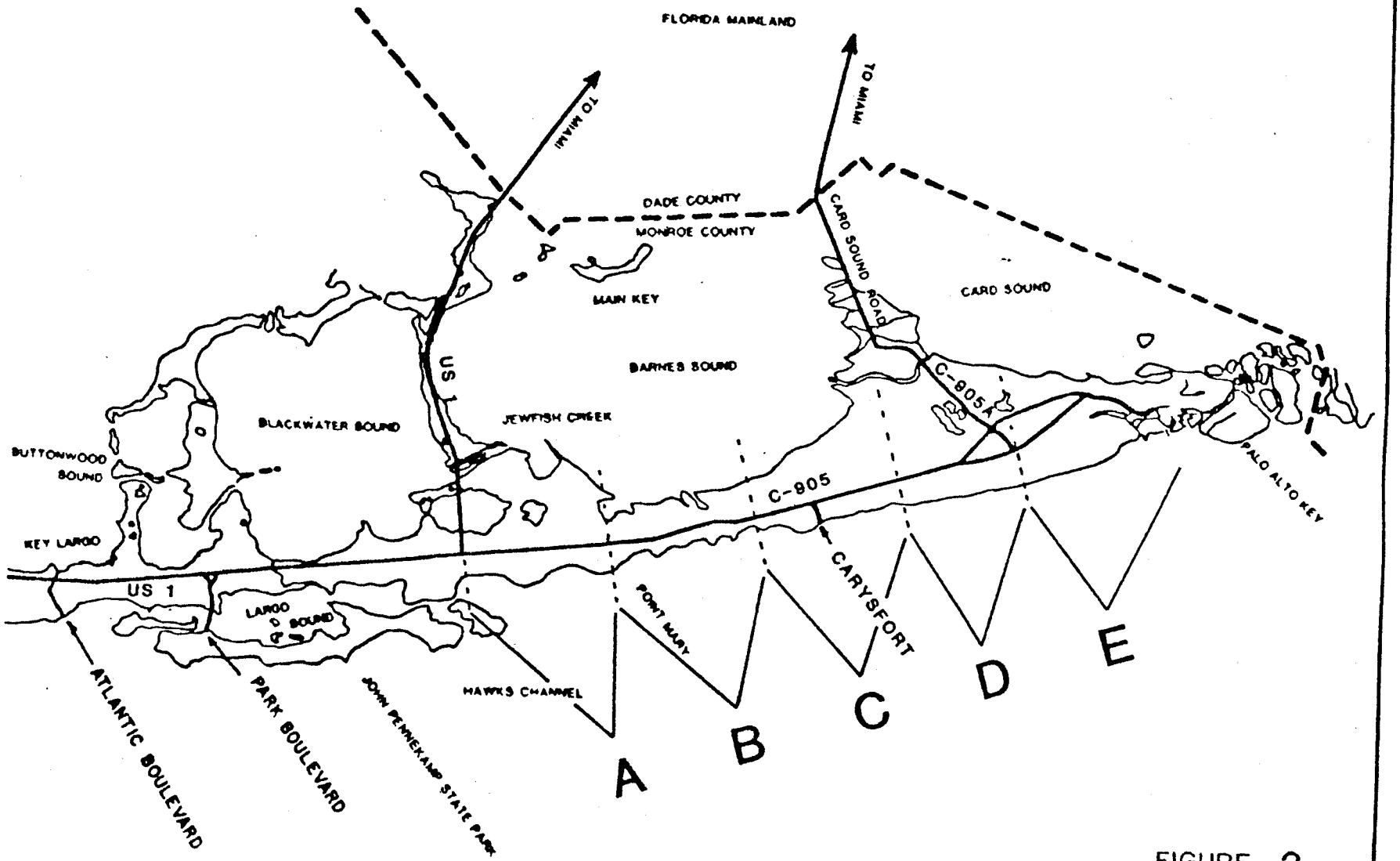


FIGURE 3

Development Scenario 2

-- The Ocean Reef Club, Port Bouganville, and Garden Cove will buildout according to their DRI proposals.

Table 2

Development Scenario 2 - Projected Volumes and Conditions

Zone	Projected Daily Traffic Volume	Existing Design Capacity	Volume/ Capacity Ratio	Level of Service
A	21855	15125	1.45	F
B	12120	15125	0.80	B
C	12120	15125	0.80	B
D	12120	15125	0.80	B
E	4910	15125	0.32	A

Traffic conditions will deteriorate on the segment south of Port Bouganville and the design capacity of this segment will be exceeded. Widening to four lanes will be needed in this area to achieve an acceptable level of service. The remaining portions of CR 905 will continue to provide acceptable traffic conditions.

Development Scenario 3

-- The Ocean Reef Club, Port Bouganville, and Garden Cove build-out as described in Scenario 2 and 3500 additional residential units are evenly distributed from U.S. 1 to north of Card Sound Road.

Table 3

Development Scenario 3 - Projected Volumes and Conditions

Zone	Projected Daily Traffic Volume	Existing Design Capacity	Volume/ Capacity Ratio	Level of Service
A	25445	15125	1.68	F
B	17820	15125	1.18	D
C	16935	15125	1.12	D
D	16935	15125	1.12	D
E	6910	15125	0.46	A

Traffic conditions will deteriorate to Level of Service F on the segment south of Garden Cove indicating a need for four lanes in this area. The segment between Garden Cove and Card Sound Road will deteriorate to Level of Service D which would be acceptable during peak traffic periods. If separate left-turn lanes are provided at the major driveways along this section, it would be necessary to construct additional through lanes. The segment

north of Card Sound will continue to provide a high level of service to motorists.

The Ocean Reef Club, Port Bougainville, and Garden Cove build-out as described in Scenario 2 and 3500 additional resort destination units are clustered as at Ocean Reef (500 units), Carysfort (1000 units) and Ocean Forest (2000 units).

Table 4

Development Scenario 4 - Projected Volumes and Conditions

Zone	Projected Daily Traffic Volume	Existing Design Capacity	Volume/ Capacity Ratio	Level of Service
A	23865	15125	1.58	F
B	16730	15125	1.11	D
C	14990	15125	0.99	C
D	14440	15125	0.95	C
E	6025	15125	0.40	A

Traffic conditions will deteriorate to Level of Service F on the segment south of Port Bouganville indicating a need for four lanes in this area. The segment between Port Bouganville and Card Sound Road will operate near design capacity, but will provide acceptable traffic conditions. Separate left-turn lanes should be provided along this roadway segment. The segment north of Card Sound will continue to provide a high level of service.

Summary of Findings

The build-out of the Port Bouganville and Garden Cove development will require the widening of CR 905 to four-lanes between U.S. Route 1 and the northernmost driveway serving them. The remaining roadway segment north of that point to Card Sound Road and the Ocean Reef Club will not require additional through lanes to accommodate the various development scenarios. However, separate left-turn lanes should be provided at all major driveway locations. The operating conditions on this segment vary by development scenario.

	Development Scenario	Level of Service
No further development	1	A
Limited development	2	B
Scattered development	3	D
Clustered development	4	C

Consideration was given to the potential closure of CR 905 between U.S. Route 1 and Card Sound Road to determine if the development scenarios could be accommodated at improved levels of service. Our findings do not support the need for this modification because the roadway needs on CR 905 will remain the same. If additional development is permitted on North Key Largo according to plans, the south end of CR 905 will require four lanes and the north end can remain as two through lanes with intersection widenings.

Specific Traffic Generation Data
(Barton Aschman Associates)

TABLE 5

Development Scenario 2 Traffic Generation

Development Zone	Project	Land Use	Size	New External Daily Traffic
A	Port Bouganville	Mixed	-	11547
	Garden Cove	Mixed	-	14619
B	-	-	-	-
C	-	-	-	-
D	-	-	-	-
E	Ocean Reef	Residential	800 units	1784
TOTAL				27950

TABLE 6

Development Scenario 2 Trip Table

From/To	Card Sound Road	U.S. Route 1	Zone A	Zone B	Zone C	Zone D	Zone E	Total
Card Sound Road	-	-	3860	-	-	-	335	4145
U.S. Route 1	-	-	9000	-	-	-	335	9335
Zone A	3860	9000	-	-	-	-	220	13080
Zone B	-	-	-	-	-	-	-	-
Zone C	-	-	-	-	-	-	-	-
Zone D	-	-	-	-	-	-	-	-
Zone E	335	335	220	-	-	-	-	890
TOTAL	4195	9335	13080	-	-	-	890	27500

TABLE 7

Development Scenario 3 Traffic Generation

Development Zone	Project	Land Use	Size	New External Daily Traffic
A	Port Bouganville	Mixed	-	11547
	Garden Cove	Mixed	-	14619
		Residential	700 units	2212
B	-	Residential	700 units	2212
C	-	Residential	700 units	2212
D	-	Residential	700 units	2212
E	Ocean Reef	Mixed	-	1784
		Residential	700 units	2212
TOTAL				39010

TABLE 8

Development Scenario 3 Trip Table

From/To	Road	Card Sound 1	U.S. Route A	Zone B	Zone C	Zone D	Zone E	Zone Total
Card Sound Road	-	-	3865	330	415	415	750	5775
U.S. Route 1	-	-	9000	500	415	415	750	11080
Zone A	3865	9000	-	275	275	275	500	14190
Zone B	330	500	275	-	-	-	-	1105
Zone C	415	415	275	-	-	-	-	1105
Zone D	415	415	275	-	-	-	-	1105
Zone E	750	750	500	-	-	-	-	2000
TOTAL	5775	1108	14190	1105	1105	1105	1105	36360

NORTH KEY LARGO, FLORIDA

HABITAT CONSERVATION PLAN

STUDY COMMITTEE FINAL REPORT

BACKGROUND DATA ELEMENT

September 15, 1986

TABLE 9

Development Scenario 4 Traffic Generation

Development Zone	Project	Land Use	Size	New External Daily Traffic
A	Port Bouganville	Mixed	-	11547
	Garden Cove	Mixed	-	14619
		Residential	700 units	2212
B	Ocean Forest	Residential	2000 units	4460
C	Carysfort	Residential	1000 units	2230
D	-	-	-	-
E	Ocean Reef	Mixed	-	1784
		Residential	500 units	1115
TOTAL				35755

TABLE 10

Development Scenario 4 Trip Table

From/To	Card Sound Road	U.S. Route 1	Zone A	Zone B	Zone C	Zone D	Zone E	Total
Card Sound Road	-	-	3575	680	420	-	545	5220
U.S. Route 1	-	-	8325	1000	420	-	545	10290
Zone A	3575	8325	-	550	275	-	360	13085
Zone B	680	1000	550	-	-	-	-	1115
Zone C	420	420	275	-	-	-	-	-
Zone D	-	-	-	-	-	-	-	-
Zone E	545	545	360	-	-	-	-	1450
TOTAL	4195	9335	13080	2230	1115	0	1450	36360

(b) AIRPORTS

Introduction

Monroe County's air transportation needs are presently served by three non-military County operated airports, and four small community airport facilities. The Key West International Airport, the Marathon Airport, and the Port Largo Airport are the

County operated facilities. The Ocean Reef Airport, the Sugarloaf Airport, the Summerland Airport, and the Tavernier Airport are the small community facilities. The Ocean Reef Airport is a privately owned and operated facility which serves and will continue to serve the residents of the Ocean Reef Club. Similarly, the Sugarloaf, Tavernier and Summerland Airports are small privately owned airstrips which will continue to serve a limited client base.

Of the two County operated facilities, only Key West International and Marathon, have long term viability. Both have adequate capacity to handle present air travel and cargo demands in the lower and middle Keys through the year 2005 with some capacity for expansion of existing facilities. The air travel situation in the upper Keys, however, is different. Because of its size and location, the County may close the only publicly operated facility in the upper Keys, Port Largo, in the near future. The result will be a dearth of public air access to the County's fastest growing area. In response to this perceived problem, the County has initiated an analysis of potential sites for a new airport facility in the upper Keys. Whether the facility is needed, however, is an issue that has yet to be determined.

OCEAN REEF AIRPORT

The Ocean Reef Airport is a privately owned and operated facility at the northern end of Key Largo that serves residents of the Ocean Reef Club. It has a 4,000 foot paved runway, with adjacent parking and a small terminal facility.

There are an estimated 7 single engine aircraft, 4 multi-engine aircraft, and 4 turbo prop aircraft based at the facility. Furthermore, several commercial airlines provide limited service between Ocean Reef and Miami.

At present the Ocean Reef Airport provides adequate service to residents of Ocean Reef, and all projections indicate it will adequately provide air service to its limited customer base through the year 2005.

A NEW COUNTY AIRPORT FACILITY FOR THE UPPER KEYS

Because of the increased growth in the upper Keys over the past decade, the projected growth over future years, and the possible closing of the Port Largo facility, Monroe County initiated an analysis to determine the need for an additional small airport facility for the upper Keys. The initial findings of the report, Upper Keys Airport Site Selection Study, showed there was a demand for a small general utility facility in the area. The Board of County Commissioners considered seven separate sites for a new facility, including two sites within the Study Area. The Board chose, however, a site on lower Key Largo and preliminary environmental assessments of that site have been

initiated, however, the Department of Transportation has made a determination not to authorize further funding for this site.

3.
POTABLE WATER

Introduction

Potable water is a subject of great irony in the Florida Keys. Surrounded by nothing but water, the Keys has no natural source of potable water other than the capture of rainwater in tanks and cisterns or through the desalinization of seawater at extraordinary expense. Nevertheless, the Florida Keys are served by a water pipeline to the mainland which, at least for the near future, has sufficient capacity to serve existing projected needs, and with additional capital expenditures, can serve the projected population through the year 2005.

In 1937, the Florida Legislature, aware that cisterns and container water could not support development of the Keys, created the Florida Keys Aqueduct Commission (FKAC). The Commission was charged with the responsibility of developing potable water facilities for Monroe County. In 1940, the FKAC reached an agreement with the United States Navy to share in the cost of a water main from the mainland. An 18" main was constructed from mainland wellfields near Florida City along the entire length of the Keys to Key West. In 1970 the Legislature replaced the FKAC with a new entity, the Florida Keys Aqueduct Authority (FKAA), which assumed responsibility for the aqueduct from the FKAC. In 1975, the U.S. Navy conveyed its interest in the aqueduct to the FKAA and in 1981 the Authority, through Farmer's Home Administration financing assistance, commenced construction of major improvements to the system.

The FKAA is presently governed by a Board of Directors. On January 1, 1985, the Board was restructured with nine appointed members; five of those members from Monroe County and the remaining members from the South Florida Water Management District (SFWMD). On July 1, 1986, the Board of Directors of the FKAA will again be reorganized to consist of five residents of Monroe County, all appointed by the Governor of Florida.

Existing Facilities and Policies

Facilities and Capacity

At present the Florida Keys Aqueduct Authority is authorized to and serves potable water to all of Monroe County (including the City of Key West) and a portion of Dade County adjacent to U.S. Highway 1 between Florida City and the Dade and Monroe County line.

The primary water source for the FKAA is the Florida City wellfield located in Dade County. Water which is drawn from

the Biscayne Aquifer is treated at the Florida City Water Treatment Plant and transported down the Keys through the pipeline. The pipeline, which extends from the Water Treatment Plant at Florida City through the Keys to Key West, has a 36" diameter from Florida City to Key Largo, 30" from Key Largo to Marathon and 24" to Stock Island with intermittent stretches of the original 18" pipeline in some locations. The FKAA has a number of water storage tank facilities along the line which have a total storage capacity of 30 million gallons system-wide.

In addition to the wellfields at Florida City, the FKAA also has the ability to receive potable water from a reverse osmosis desalinization plant which is maintained in stand-by condition on Stock Island. This plant has a production capacity of 2.7 million gallons per day, and is available for use during system emergencies, shut-downs, or peak consumption periods. According to the FKAA, the facility can be brought into full production within four (4) hours.

The FKAA has approximately 420 miles of distribution lines ranging from 3/4" to 8" in diameter. At present, many of these pipes are severely deteriorated, or inadequate in size. In 1982 the FKAA implemented a program to upgrade the distribution system which is funded by a surcharge based on a ten year schedule.

In addition to replacing inadequate or undersized lines, the program is also designed to enable the use of the system for fire protection. Historically, the FKAA, because of the small size of the transmission and distribution lines and lack of adequate storage and pumping facilities, has not had sufficient water supply pressure to provide satisfactory fire protection. The new distribution systems are designed to provide fire flows of 750 GPM to residential areas and 1500 GPM to commercial, industrial and to high density residential areas. However, until additional storage and pumping facilities are constructed, the water for fire flow in these lines will not be available.

Service Area

The FKAA provides potable water throughout its service area with the exception of portions of the Keys designated as critical habitats for species designated as endangered under the Federal Endangered Species Act. In these areas, the FKAA is barred from providing service pursuant to its financing agreement with the FMHA as stated in its Letter of Conditions dated September 26, 1978 and subsequent amendments. Those areas which are currently barred from service on North Key Largo are:

(1) Crocodile Lake National Wildlife Refuge. The Crocodile National Wildlife Refuge, with the exception of existing private residences located in Section 29, Township 60 South, Range 40 East.

(2) Schaus Swallowtail Butterfly Habitat. The prime Schaus Swallowtail Butterfly habitat is in North Key Largo. This area includes the upland portions of the following sections or quarter sections: T59S, R40E, SE-1/8 Section 13, Section 24, Section 25, T59S, R41E, Sections 18, 19.

It is expected that a successful Habitat Conservation Plan, which would lead to a section 10(a) permit from the federal government for "incidental" taking, would allow the FKAA to provide water for development recommended by the plan.

4.
WASTEWATER TREATMENT

Introduction

The treatment and disposal of wastewater is primarily a matter of private initiative in Monroe County. It is regulated by the state Department of Health and Rehabilitation Services (HRS) and the Department of Environmental Regulation (DER). There are no public wastewater treatment facilities in the Florida Keys; however, the City of Key West does have a wastewater collection system.[1/] According to available data, approximately 65% of all wastewater produced in Monroe County, excluding that from the City of Key West, is treated by individual on-site treatment facilities -- septic tanks. The balance of the wastewater is treated by package plants. The bore holes for package plant effluent are from 10 - 90 feet deep with very few less than 20 feet. All bore holes installed in the last 5 - 7 years are at least 35 ft. deep with 20 - 30 ft. of casing.

Existing Facilities

Septic Tanks

The most commonly used septic tank system in Monroe County is the single tank system. Standards for on-site wastewater treatment facilities have been established for Monroe County by HRS and are implemented by the Monroe County Department of Health. Little, however, is actually known about the effectiveness of septic tanks in the Keys or about the long-term implications of septic tank use on Keys' water quality, except that there are no known obvious problems of surface water pollution in conjunction with septic tank usage. Numerous studies of canal systems have been made since 1973 as well as open water discharge areas from wastewater treatment plants. Except for raw sewage discharges, or improperly installed septic tank systems, the surveys showed that the major pollutants were nutrients. Bacteriological tests were seldom in violation of state regulations, except under the previously noted conditions.

1/ The City of Key West discharges untreated wastewater into the Atlantic Ocean through an outfall system.

The Division of Health and Rehabilitation Services takes the position that properly designed, installed and maintained septic tanks are an appropriate means of wastewater treatment in the Keys and has no plans for any in depth research regarding pollutant migrations from septic tank discharge points.

Package Treatment Plants

Package plants are required to achieve secondary treatment (90% BOD) before discharging effluent into subsurface limestone formations at 10 to 40 foot depths. The Ocean Reef Club operates the only package plant on North Key Largo. It has a design capacity of 0.35 MGD.

As with septic tanks, little is known about the long-term impacts of current discharge practices of package plants on Monroe County water quality. Pollution from wastewater treatment plants with open water outfalls give the most immediate indication of the extent of water pollution. From 1977 to the early 1980's several intensive surveys were conducted by the DER at the outfall area of several wastewater treatment plants. None of the sites, including Sigsbee Park Naval Housing, Key Haven Utility, the Community College, the County Public Service Building, NUAGE Utility and Key Colony Beach, had degraded the water quality sufficiently to require a mixing zone. The Florida Department of Environmental Regulation has recently initiated a series of monitoring programs; however, there are no known water quality problem areas that are attributable to package plant discharges.

DER requires that each private wastewater facility have a certified operator responsible for monitoring the treatment progress to insure DER standards are met. The operator is required to submit monthly reports which are monitored by DER officials. In addition, and to further insure that private wastewater treatment facilities meet DER requirements, local Marathon personnel inspect each site at least once a year, test the plant effluent if it appears to be out of limits, and observe and report on maintenance of the system. To date, DER records show that overall, plants have been operating above standards. 2/

Even though the present facilities are generally operating within standards, there is always the concern that eventually there will be a breakdown in maintenance, with a concomitant detrimental effect on Keys' water quality even though at present DER officials do not view this as a problem.

2/ Interview with officials in DER, Marathon, Florida office.

5.
SOLID WASTE DISPOSAL

Introduction

The Monroe County Municipal Service District (MSD) is responsible for the collection and disposal of solid waste in the unincorporated part of Monroe County. The District is a special taxing district empowered to finance the collection and disposal of solid waste through service charges and special assessments. Solid waste is collected by franchise agreements with seven operators who deliver waste to the District's three disposal sites.

Existing Facilities

Waste Collection

The District has established franchise agreements for the collection of solid waste. The franchises are granted for five year periods. On North Key Largo, there are two separate operators, Keys Sanitary Service, and Ocean Reef, Inc. All residences and businesses in the unincorporated area of Monroe County use these sanitation services and pay rates set and approved by the Board of MSD. Residential collection is twice weekly throughout the County. Frequency of commercial collection varies.

Disposal Facilities

The Monroe County Municipal Service District owns and operates three waste disposal sites located on Cudjoe Key, Long Key and Key Largo. The Key Largo site has a remaining life of approximately three years. The Long Key site has a remaining life of approximately four years. The third site, on Cudjoe Key, is available for continued service through 1994.

KEY LARGO

The Key Largo site, which serves Subdistrict I, is located to the northwest of State Route 905 mid-way between U.S. 1 and the Card Sound Road. The 15 acre site serves the area from the Dade County line to Snake Creek at the lower end of Plantation Key. The facility operates three incinerators with a capacity of processing approximately 112 tons of waste per day.

Eight acres of the site is in actual landfill, of which 3.8 acres is unused. This unused area has the remaining capacity to absorb 140,000 cubic yards of fill. Based upon historical data and other local information, MSD and DER officials project that the population served by the Key Largo land fill presently generates approximately 39,148 cubic yards of solid waste a year, which after a final cover of 16,950 cubic yards means the site has approximately 3 years before it is at capacity. This is an

extremely troubling situation because expansion of the facility through the acquisition of additional land is impractical, given the inclusion of the area in the Crocodile Lake National Wildlife Refuge.

6.
ELECTRICAL FACILITIES

Introduction

North Key Largo is served by the Florida Keys Electric Cooperative Association (FKEC), an entity created by special act of the Florida legislature, whose service area begins at the east end of the Seven Mile Bridge at Marathon Key, and runs north to the County line.

Engineering and planning analysis shows that the FKEC system, primarily because of its ability to buy power from the mainland, has sufficient capacity and financing sources to provide cost efficient electricity through 2005.

In October, 1983, the USFWS issued a jeopardy opinion to REA (which would have provided the FKEC with funding for a substation on North Key Largo) which basically prohibited electric service in endangered species habitat. Since the species of concern were the American crocodile and the Key Largo woodrat and Key Largo cotton mouse, the service restriction covered the mangrove areas with the Crocodile Lake National Wildlife Refuge as well as the hammocks running along the center of the Key. This prohibition basically halts further development of undisturbed lands in the area. This restriction can only be lifted by showing no jeopardy to the animals listed as endangered.

Existing Facilities

Generation. Because of the high cost of generating its own power as compared to the cost of purchasing power from Florida Power and Light (FP&L) on the mainland, the power requirements of the Florida Keys Electric Cooperative Association (FKEC) are met primarily through the purchase of power from FP&L and the use of a diesel generating facility at Marathon to provide voltage support and meet peak demands. If limited use and routine maintenance continues, the Marathon generator is expected to last until 2005.

Transmission and Distribution. FP&L transmits the power it sells to FKEC from a Florida City substation through a 138 KV transmission line and a 69 KV transmission line. The FKEC transmission system consists of 61.7 miles of 138 KV line and transformation capacity of 128 MVA. The 138 KV transmission line was completed in 1982. It is designed to withstand 150 mph winds and has the capacity to meet the electric demand projected to the year 2005.

Additionally, FKEC owns many miles of above and below ground distribution lines, and requires that ground extensions on private property be paid by the customer. At no charge to the customer, the line will be brought to the edge of the property. Underground lines installed by a land developer must be approved by FKEC before connections are allowed, and once they are approved, the utility accepts ownership of the lines.

7.
POLICE FACILITIES

Introduction

Police protection is provided to the unincorporated parts of Monroe County by the Monroe County Sheriff, a constitutional officer elected at large for 4 year terms. By statute, the Sheriff is required to maintain his office in the county seat, the City of Key West; however, the Monroe County Sheriff's Department operates two additional offices at Marathon and Plantation Key. In addition to serving as conservator of the peace, the Monroe County Sheriff is responsible for maintenance and operation of the County's correctional facilities.

Existing Facilities and Personnel

General Office Facilities

The Sheriff's headquarters are located in the Jackson Square County Administrative Complex in the City of Key West. Communications are provided by a multi-frequency radio net which is controlled by a fixed base station located within each service district. The radio system was upgraded in 1977 but still requires additional equipment to effect a complete and efficient system.

Command and control is attained using the radio net dedicated telephone lines between headquarters and all district commands, and a teletype network having terminals at each district and headquarters. This teletype network is part of the state law enforcement system which interfaces with the National Law Enforcement Teletype System and the National Crime Information Center.

For the purpose of more efficiently managing and providing law enforcement services, the department has divided its jurisdiction into three operational service districts. The offices for District III, which includes North Key Largo under its jurisdiction, are located at the County governmental complex on Plantation Key. It shares a building with several other governmental functions.

The service district provide continuous law enforcement services, 24-hours a day. Citizen calls for service are received by communications personnel who route them via radio to responding mobile police units assigned in the service district.

Jail Facilities

The Monroe County main facility is located in the Jackson Square Administrative Complex in Key West. The Sheriff's Department operates a minimum security facility with a capacity of 24 beds at the Public Service Building on Stock Island; the two stations on Marathon and Plantation Key also have temporary holding facilities.

Present Demand

Patrol Deputies and Cars

The Monroe County Sheriff's Department employs a patrol allocation model as a measure of present demand for police services. Factors considered include deputies per household which at the present time is one deputy for every 663 dwelling units and one deputy for every 46.53 commercial unit. There are currently 19 patrol deputies in District III, and the patrol allocation model indicates that at present there is a deficiency of 7 police officers in the Upper Keys.

8.
FIRE PROTECTION AND EMERGENCY MEDICAL SERVICES

Introduction

Fire protection services in North Key Largo are provided through a Municipal Service Taxing Unit and a private fire department at the Ocean Reef Club. The North Key Largo fire department is operated on a volunteer basis. Coordination of services and the administration of the taxing unit's affairs are provided by the County Office of Emergency Services. Pursuant to Florida statute, the district levies its own millage and collects its own taxes.

District 6 which runs from Key Largo to the Card Sound Toll Road, is served by a fire station in Key Largo which has three pumper trucks, two rescue/pumper vehicles, and an Aerial Telesquirt Pumper. The Aerial Telesquirt Pumper Truck has a reach of up to 55 feet in height.The Ocean Reef Club encompasses all of District 7. It is served by a single fire station.The current response times for the Key Largo and Ocean Reef stations are 4.1 minutes and 2 to 3 minutes, respectively.

Emergency Medical Services on North Key Largo are provided by contract with Volunteer Ambulance Corp., which has service from Rock Harbor, and by Ocean Reef Medical Center (serving Ocean Reef exclusively). Response times are 3.6 minutes and 5.0 minutes respectively.

9.
MEDICAL SERVICES

There are four acute care general hospitals serving the County: Florida Keys Memorial Hospital, the DePoo Hospital, Fisherman's Hospital, and Mariner's Hospital.

The closest facility to North Key Largo is the Mariner's Hospital located in Key Largo with 42 beds, out-patient and operational facilities. It utilizes a nearby heliport and contracts with the County for ambulance services.

10.
EDUCATIONAL FACILITIES

The Monroe County School Board has the responsibility for educating the school age children throughout the County (including all children of military personnel). North Key Largo is part of Sub-District One, which includes Coral Shores High School, and Key Largo and Plantation Key Elementary School. Both elementary schools are currently at or above capacity.

11.
LIBRARY FACILITIES

Introduction and History

Library services in Monroe County are provided by one of ten (10) administrative divisions of County government. The system was established by the Monroe County Board of County Commissioners for the purpose of operating and maintaining a free public library service for the citizens of the County, and is governed and funded through a Library Advisory Board and the Monroe County Board of County Commissioners.

The County's branch libraries are located in Marathon, Islamorada and Key Largo. The Key Largo branch library, holds 16,735 books in a 1,880 square foot facility.

12.
HURRICANE PROTECTION

Introduction

Statistically, Monroe County has one of the highest probabilities of being effected by tropical storms and hurricanes and it is simply a matter of time before the Florida Keys are subjected to high winds and storm surge as a result of a tropical hurricane. Since 1900, the Florida Keys have been affected by 19 storms, 18 of which passed the Keys during the months of September, October and November. (See Tables 1 and 2)

Table 1:

NUMBER OF HURRICANES SINCE 1900 IN MONROE COUNTY BY MONTH

Month	Monroe County
June	0
July	0
August	1
September	8
October	9
November	1
December	0
TOTAL	19

Table 2

NUMBER OF HURRICANES SINCE 1900 IN MONROE COUNTY BY SAFFIR/SIMPSON SCALE NUMBER

Saffir/Simpson Category 1/	Number of Hurricanes
1	2
2	6
3	8
4	2
5	1
Total	19

Hurricane events in the Florida Keys have involved winds in excess of 155 mph and storm tides or surges that completely inundate the Keys.

The National Hurricane Center recommends that residents of low-lying, exposed areas be evacuated to shelters on high ground in advance of hurricane arrival. Unfortunately for the

1/The Saffir/Simpson Hurricane Scale is used by the National Hurricane Center to give public safety officials a continuing assessment of the potential for wind and storm-surge damage from a hurricane in progress. Scale numbers are made available when a hurricane is within 72 hours of landfall. Scale numbers range from 1-5. Scale number 1 are hurricanes with sustained winds of 74-95 m.p.h. No. 2 are hurricanes with sustained winds of 96-110 m.p.h. No. 3 are hurricanes with sustained winds of 111-130 m.p.h. Scale No. 4 are hurricanes with sustained winds of 131-155 m.p.h. And, Scale No. 5 are hurricanes with sustained winds of over 155 m.p.h.

Florida Keys, the time available for evacuation, that is, after a formal National Hurricane Center forecast of landfall is issued, is inadequate for the evacuation of the Keys' population. It is estimated that it would require approximately 31 hours in the worst case situation to evacuate the population of the Florida Keys by way of the County's only evacuation route, U.S. 1. Unfortunately, the National Hurricane Center is only able to provide 12 - 24 hours of warning, a period of time that may be seriously foreshortened by pre-hurricane hazards such as squalls with gale force winds and storm tides.

The National Hurricane Center recommends that all persons be evacuated from off-shore islands in advance of hurricane arrival and that vertical evacuation be considered a refuge of last resort. In Monroe County the reasons for this recommendation are obvious -- a refuge that is susceptible to flooding or wind damage is no refuge at all. Moreover, the remoteness of the Keys in the event of blockage or damage to U.S. 1 makes post-disaster recovery extremely difficult where evacuees are scattered about in small clusters. Of particular concern is emergency medical services to the retirement age population in the Keys.

Existing Facilities

There are several designated hurricane shelters in the Upper Keys. They are all located in public schools. Each of the evacuation shelters will be flooded by a serious hurricane and none of the structures are constructed to withstand sustained winds in excess of 125 mph.

13.
PARKS AND WILDLIFE REFUGES

a.
State Parks
JOHN PENNEKAMP CORAL REEF STATE PARK

In 1957, in response to the exploitation of the reefs of Key Largo, the State of Florida designated the territorial waters and submerged lands off the Atlantic coast of Key Largo as the John Pennekamp Coral Reef State Park. Pennekamp State Park extends for 21 nautical miles along the Atlantic coast of Key Largo, and runs seaward from the shoreline to the three mile limit of Florida's territorial jurisdiction (See Figure 2). In addition to these 27,360 acres of submerged lands, the park also includes 2,339 acres of upland with several swimming beaches, picnic areas, dive boat operations with trips to the reef, and other concessions.

In 1975, the United States government, pursuant to the Marine Protection Research and Sanctuaries Act, designated the waters seaward of Pennekamp Park as the Key Largo Coral Reef National Marine Sanctuary. The Sanctuary extends longitudinally

for 21 nautical miles directly adjacent to the seaward boundary of the Pennekamp State Park, and averages about five and one-half nautical miles wide. The purpose of the sanctuary designation is to protect and preserve the Key Largo coral reef system in its natural state.

Together, the Marine Sanctuary and Pennekamp State Park cover approximately 178 square nautical miles in which rests the most extensive living coral reef system in the continental United States. Dozens of different species of coral are found in the Key Largo reefs, including staghorn, club-finger, moosehorn, star head, and fern coral. In addition, the park also supports over one hundred different species of marine life.

NEW MAHOGANY HAMMOCK

The state currently owns, or is in negotiation for purchase of, over 800 acres of pristine hammock in North Key Largo. The site is located on the Atlantic side, south of the Ocean Reef Club. The tract includes the Dilworth properties and the Dynamite Docks. The hammock is currently considered by the State to be a botanical preserve site, and there are no plans for active recreation there in the near future. The hammock is currently home to both the Key Largo woodrat and cotton mouse, and in the recent past served as habitat for the Schaus swallowtail.

b.

NATIONAL REFUGES AND SANCTUARIES

CROCODILE LAKE NATIONAL WILDLIFE REFUGE

In October, 1978, the Fish and Wildlife Service of the Department of Interior proposed, and the Secretary of the Department of Interior designated, 7,100 acres of land in North Key Largo as Crocodile Lake National Wildlife Refuge. (See Figure 1) The Refuge, which borders Barnes and Card Sounds on the east, consists primarily of shoreland mangroves and tropical hardwood hammocks. The tropical hardwood hammocks in this area of North Key Largo constitute the most extensive stands of such vegetation in Monroe County and the United States.

The Crocodile Lake National Wildlife Refuge harbors a number of endangered and threatened species, including the American Crocodile (*Crocodylus acutus*), the West Indian Manatee (*Trichecus manatus latirostris*), the Schaus Swallowtail butterfly (*Heraclides aristodemus ponceanus*), the Key Largo Woodrat (*Neotoma floridana smalli*), the Key Largo Cotton Mouse (*Peromyscus gossypinus allapaticola*), and the Eastern Indigo Snake (*Drymarchon corais couperi*). The management plan for the Refuge calls for passive recreational opportunities for the area.

KEY LARGO CORAL REEF NATIONAL MARINE SANCTUARY

As is outlined above, in 1975 the United States government designated the waters seaward of Pennekamp State Park as the Key Largo Coral Reef National Marine Sanctuary. It extends longitudinally for 21 nautical miles directly adjacent to the seaward boundary of Pennekamp State Park. The purpose of the Sanctuary is to preserve the Key Largo coral reef system. In furtherance of this effort, the marine sanctuary and state park are under joint management of the state and federal governments.

14.
GENERAL GOVERNMENTAL SERVICES

Introduction

Monroe County government, established pursuant to Article VII, Section 1 (a) and (f) of the Florida Constitution, is led by the Monroe County Board of County Commissioners, which aided by a County Administrator, guides the operation of ten departments providing a broad scale of general health and welfare services to the citizens of Monroe County (See Figure 1). These departments include: the Extension Service, the Veteran's Department, the Social Services Department, the Health Department, Public Works, Planning and Zoning, County Airports, Building, the County Library, and the Office of Civil Defense. The services they provide range from provision of general social and health care delivery, to operation and maintenance of the County's buildings, roads and parks, to general planning and monitering of land development, to preparation for a hurricane strike.

Departments of County Government and Services

Social Services

The Social Services Department, working both independently and in conjunction with the Florida Department of Health and Rehabilitative Services (HRS), provides a wide range of general health and social programs to the citizens of County. Programs in which the department works includes welfare administration and welfare services, an ACLF (Adult Congregate Living Facility) - Bay Shore Manor, a transportation program, a homemaker program, a Community Care for the Elderly (CCE), a nutrition program and a Senior Community Service Program (SCSP).

The welfare administration, welfare services, transportation program, and Bay Shore Manor are funded through County taxes. The remainder of the programs are funded through grants which are matched by funds from the County.

The welfare program offers emergency and temporary assistance basically for the aged and the disabled while assistance of a permanent nature is pending. Households with children

or single individuals can be considered for assistance on a case by case basis, depending on the circumstances. There is income and asset eligibility for services paid, if the individual or household is eligible. Depending on individual basis, the following services are offered:

in-patient care	out-patient care
physician services	prescriptions
tuberculosis care	food and dietary
prosthetic devices	medical supplies
shelter	utilities
medicaid	nursing home and hospital payments
clothing	indigent/pauper burials
transportation (bus fare)	

Health Department

The Monroe County Health Department was first created in conjunction with the State of Florida to aid in the control of communicable diseases and later to provide better care for babies and mothers in order to lower infant and maternal death rates.

The Health Department provides a wide range of medical and dental services to citizens in the County including a walk-in clinic, immunization for children, a venereal disease clinic, family planning, well-child clinic, a medicaid child clinic, clinics for tuberculosis, diabetes, epilepsy and other diseases, cardiovascular screening, pregnancy information and fitness programs. The Department also runs the school health program in conjunction with the Monroe County School Board.

In addition to providing these services, Health Department employees work in conjunction with private groups in the community to establish and operate the Wesley House Community Center (a child care center designed to meet the needs of working parents), Grace Jones Day Care Center, the Big Brother and Big Sister Program, a Foster Families Program, Parent Aid Program, Domestic Abuse, and the Monroe County Older Americans Advisory Board.

Public Works

The Monroe County Public Works Department is responsible for the operation and maintenance of the County owned facilities. This includes the County roads; County buildings (including the Courthouses, annexes, and administrative facilities); the County parks; and the County animal shelters.

In addition, the Public Works Department aids the Office of Civil Defense in its disaster preparedness efforts.

Planning and Zoning

The Planning and Zoning Department is responsible for all planning for the County as well as the administration and enforcement of the County's Comprehensive Plan.

Building

The Monroe County Building Department is responsible for the administration and enforcement of all ordinances applicable to building, construction, and explosives. The Building Department has offices in Key West, Marathon, and Plantation Key, at which inspectors are based to insure the appropriate laws are being followed.

Airports

The Monroe County Airport Department is responsible for the operation and maintenance of the County's two airports: Key West International and the Marathon Airport. Even though the County funds much of the operating budget for these facilities, the Department also receives a significant amount of funds from the Federal Aviation Administration.

Libraries

The Monroe County Library is responsible for the operation of the County's four libraries in Key West, Marathon, Islamorada, and Key Largo. Library cards are available at no cost to permanent and legal residents of Monroe County.

The Library facilities include a reference division, a Florida history department, a children's department, film programs, a general reading collection, periodicals, and a bookmobile.

Office of Civil Defense

The Monroe County Office of Civil Defense serves as the central clearing house for all public information in the event of an emergency, and is the coordinating unit for all disaster control and response programs.

Specific responsibilities of the office include: (1) development of procedures to reduce the impact of natural or man-made disasters on the citizenry and property in the Keys; (2) preparation for possible disaster through public education; (3) coordination of County resources in an actual emergency; and (4) implementation of all measures required to return life to normal as soon as possible in the wake of a disaster.

The major focus of the office, however, is hurricane preparedness, and the office has prepared a Hurricane Evacuation Plan.

Extension Service

The Monroe County Extension Service offers general horticultural and marine science services to the residents of the County. The office offers informal education on local horticulture, marine science and home economics; responds to direct mandates from the County Commission; aids in planning and providing man-made habitats to help support game fish populations; and provides other general horticultural and marine science services.

Veteran Affairs

The Veteran Affairs Department acts as liaison between the 14,000 veterans in Monroe County and the Veterans Administration. It aids active duty personnel and veterans in their receipt of: (a) compensation for service related disability; (b) educational benefits; (c) home loans; (d) out-patient treatment and hospitalization; (e) insurance claims and social security appeals; and (f) burial allowances and widows' benefits.

CHAPTER III.

Threatened and Endangered Species

A. Animals

There are four federally-listed endangered animal species living on North Key Largo. They are the American Crocodile, the Key Largo woodrat and cotton mouse, and the Schaus swallowtail butterfly. The crocodiles live and breed in the shallow mangrove areas on the Barnes Sound side of the Key. The other three species inhabit the tropical hardwood hammock areas on the upland portion of the Key.

There are several other animals listed as threatened or endangered by the State of Florida. They are shown in Table III-1.

Table III-1:
THREATENED AND ENDANGERED SPECIES ON NORTH KEY LARGO

Common Name	Scientific Name	Federal Status	State Status
American crocodile	*Crocodylus acutus*	E	E(FGFWFC)
Schaus swallowtail butterfly	*Heraclides aristodemus ponceanus*	E	E(FGFWFC)
Key Largo woodrat	*Neotoma floridana floridana*	E	E(FGFWFC)
Key Largo cotton mouse	*Peromyscus gossypinus allapaticola*	E	E(FGFWFC)
Eastern indigo snake	*Drymarchon corais couperi*	T	T(FGFWFC)
White-crowned pigeon	*Columba leucocephala*	C	T(FGFWFC)
Rim-rock crowned snake	*Tantilla oolitica*	C	T(FGFWFC)
Tamarindillo	*Acacia choriophylla*		E(FCREPA)
Powdery catopsis	*Catopsis berteroniana*		E(FDA)
Prickly apple cactus	*Cereus gracilis* var. *simpsonni*	C	E(FDA)
Silver palm	*Coccothrinax argentata*		E(FDA)
Lignum vitae	*Guaiacum sanctum*		E(FDA)
White Ironwood	*Hypelate trifoliata*		T(FCREPA)
Mahogany mistletoe	*Phoracdendron rubrum*		T(FCREPA)
Florida thatch palm	*Thrinax floridana*		T(FDA)
Brittle thatch palm	*Thrinax microcarpa*		T(FDA)

E = Endangered
T = Threatened
C = Candidate for Federal Listing
FCREPA = Florida Committee on Rare and Endangered Plants and Animals
FDA = Florida Department of Agriculture and Consumer Services (Section 581.185-187, Florida Statues)
FGFWFC = Florida Game and Freshwater Fish Commission list, Section 39-27.03-.05, Florida Administrative Code

1.

CROCODYLUS ACUTUS

American Crocodile

The American crocodile is found in several areas of tropical coastal swamps throughout the Caribbean basin and the Pacific coast of Central and South America. In the U.S., it occurs from Biscayne Bay on the east coast of Florida to the Ten Thousand Islands on the west coast, although the breeding habitat is much more restricted.

The American crocodile inhabits coastal waters, with a preference for protected bays and sounds, and adjacent mangrove swamps. It utilizes man-made bodies of water such as canals and borrow pits if other conditions are suitable. It requires loose soils above the elevations of tides for its nest sites, where the females lay eggs. Natural nesting sites are usually located on beaches or the waterward areas of tropical hardwood hammocks. Deep water access for the adult female close to a potential nest site appears to be a second requirement for nesting (Ogden, 1978 a). It may utilize soils deposited by man as a result of dredge/fill activities for its nesting sites, given that other conditions are favorable. Nesting activity begins in April when the females re-work nest sites or establish new ones. The females lay 20 to 80 eggs in late April or early May; the young hatch in late July or early August and are dug out by an adult, presumably the female (Ogden, 1978b).

Adult crocodiles feed on fish, crabs, birds and turtles. Juveniles feed on small fish and arthropods (U.S. Fish and Wildlife Service, 1984).

The crocodile, like other large carnivores, requires extensive areas of habitat for its survival, although there are not sufficient data to estimate the range requirements for an individual animal. Tagged individuals have been known to move four miles within two months of hatching, and eight miles 1.5 years after hatching. Crocodiles are known to cross highways, as road kills occur on U.S. Highway 1 (between Key Largo and Florida City) and juveniles tagged in Barnes Sound have been recaptured east of county road 905 on Upper Key Largo (pers. comm., Paul Moler, Fla. Game and Freshwater Fish Commission, Gainesville, Florida).

The current Florida crocodile population is seriously depleted compared to estimates of the historic population. Ogden (1978 a) estimated that the population at the beginning of the 20th century was 1,000 to 2,000 animals, and hunting by settlers had probably already taken place. Ogden (1978 a) estimated that there were 100 to 500 crocodiles in Florida at the time of his study (early 1970's), and current studies corraborate that estimate (pers. comm., Paul Moler). Based on nesting activity there are approximately twenty reproductively active females in the

U.S. (Ogden, 1978 a; pers. comm., Paul Moler). The reproductive population appears to be stable in the recent short-term, as there have been approximately twenty nests per year since the early 1970's (pers. comm., Paul Moler). However, there have been no censuses of nesting activity within Everglades National Park for the last three years.

The Florida Keys comprise a critical portion of the American crocodile's range in the U.S. In recent years, crocodiles have nested in two locations in the Keys, one in the Lake Surprise area and the other on the bay side of Upper Key Largo (exact locations are not specified due to the sensitivity of nesting animals to any human activity). There are three to six nests per year in the Keys, which represents about 30% of all crocodile reproduction in the U.S. (pers. comm., Paul Moler). This rate of nesting activity is probably indicative of an estimated Upper Key Largo population of 120 to 150 animals (pers. comm., Paul Moler). In 1984, four or five of the six nests in the Keys hatched successfully (pers. comm., Paul Moler).

The bay side of Upper Key Largo is good crocodile habitat because there are suitable nesting sites close to extensive areas of undisturbed habitat. In contrast, the mainland side of Barnes Sound and other areas have sufficient feeding habitat but no suitable nesting sites (Ogden, 1978 a). Crocodiles are also known to be present in the Lower Keys in the area of Big Pine Key. However, there is no evidence of a reproductive population (Jacobsen, 1983; U.S. Fish and Wildlife Service, 1984). Outside of the Keys, the other nesting sites are on the mainland of Florida within Everglades National Park, on mangrove islands in Florida Bay within Everglades National Park, and at Turkey Point in Biscayne Bay.

The range of the crocodile has progressively decreased in recent years. Ogden (1978 a) noted a large-scale and continual shrinkage in the range from the 1930's through the 1970's, as nesting and feeding sites were progressively abandoned in the Keys and elsewhere in Florida.

The decline of the crocodile in the U.S. is directly attributable to human activities. Historically, elimination of wetland and open water habitats by dredging and filling for urbanization has been a major factor. Although outright destruction of habitat has decreased due to Federal and State wetland regulations, degradation of suitable habitat continues, and is attributable to increased human population and activity in crocodile areas. Crocodiles are, on the average, intolerant of human activities and persistent boat traffic, and thus continue to be driven out of otherwise suitable habitats by increased presence of humans. Although this can occur at any life stage, it is particularly important for nesting areas, as the females will revisit a nest several times after laying eggs, and dig out the hatchlings, transporting them to nearby water. Just as important is that people are generally intolerant of crocodiles, which are

perceived as threats to safety. Thus, increased encounters between people and crocodiles, as a result of increased human population or access, increases the probability of deliberate harassment or killing of crocodiles.

The vast majority of known crocodile mortalities are man-related (U.S. Fish and Wildlife Service, 1984). Road kills are a major factor. In recent years, there have been three documented road kills per year when crocodiles have attempted to cross over U.S. Highway 1 between Key Largo and Florida City, and occasional road kills along county road 905 and the Card Sound Bridge Road (pers. comm., Paul Moler). Deliberate killings of crocodiles do occur, although this is thought to be less of a factor than road kills (U.S. Fish and Wildlife Service, 1984; pers. comm., Paul Moler). Natural mortality rates and causes are not known (U.S. Fish and Wildlife Service, 1984).

2.
NEOTOMA FLORIDANA SMALLI

Key Largo Wood Rat

The Key Largo woodrat is an endemic subspecies that exclusively inhabits tropical hardwood hammocks and does not utilize any other vegetation community. The nearest mainland population of N. floridana is north of Lake Okeechobee (Layne, 1974; Hersch, 1981).

The range of the woodrat formerly extended to southern Key Largo; Schwartz (1952; cited in Barbour and Humphrey, 1982) reported capturing two individuals at the southern end of Rock Harbor. At present, the natural range of the woodrat is limited to hammocks in Upper Key Largo (Barbour and Humphrey, 1982). It is also found on Lignum Vitae Key, where it was introduced in 1970. Further investigation to determine whether the remaining portion of Key Largo also has woodrats occured during the fall of 1985 and spring of 1986. Trapping efforts south of the U.S. 1/S. R. 905 intersection produced no woodrats or cotton mice.

The wood rat is nocturnal and primarily herbivorous, consuming the leaves, seeds, buds and fruit of hammock plants (Brown, 1978). Reproductive rates are low for a rodent, averaging two litters per year, each containing an average of two young (Brown, 1978). The wood rat is known for its construction of distinctive stick houses, which it uses as nests and refuges. Hersh (1978; cited in Barbour and Humphrey, 1982) estimated that there were 5.6 nests per animal in her study area. Woodrats also use holes beneath tree roots in limestone as refuges (Goodyear, 1985).

Usually, due to their arboreal nature, woodrats utilize only hammocks that are sufficiently mature to have a well-defined canopy. In addition, Barbour and Humphrey (1982, pg. 147) con-

cluded that in their study "the abundance of woodrats was directly related to the maturity of the forest in which they lived." Immature hammocks in Upper Key Largo, if allowed to regrow, will probably become suitable habitat for woodrats given the proximity of viable woodrat populations.

The population status and range requirements of the woodrats have been estimated in two studies. Hersch (1981) estimated that the average home range for a woodrat is 2,370 square meters (0.59 acres). Hersch (1981) calculated an average density of 2.2 animals per hectare (0.89 animals/acre). Hersch's study was limited to one Upper Key Largo hammock chosen for its high density of woodrat nests.

Barbour and Humphrey (1982) surveyed most of the hammocks of Upper Key Largo for woodrats. They found an average density throughout the range of 1.4 animals per hectare (0.56 animals/acre), extrapolating from Hersch's (1978) value of 5.6 nests per animal. Their data indicated that the density of nests and animals was positively correlated with the maturity of the hammock.

In a study involving extensive grid trapping by Humphrey in the spring of 1986, density estimates were far higher than previously believed. In areas with woodrats, Humphrey found a range of 3.9 woodrats per acre. This is approximately five times the number of animals expected by extrapolating from the number of visible woodrat stick houses.

Goodyear (1985) estimated home range using radiocollars and flourescent dust tracking. In the limited dust capsule tracking work completed to date, it appears that woodrats tend to use the same holes, vines, and pathways for travel on consecutive nights. Further home range work is in progress during the fall of 1985. Spring research indicated a home range of 600 to 1600 square meters, far less than Hersch's (1982) estimate. The Goodyear (1985) research includes no estimate of density. Research this fall is intended to establish density in various hammock areas, with the hope of relating density to hammock characteristics.

Barbour and Humphrey (1982) estimated the total population of woodrats in Upper Key Largo to be 654 individuals. Humphrey (1986) estimates that the woodrat density is about three times larger than the level for other subspecies of eastern woodrat. The data show that woodrat density can reach seven times the level found by Hersch (1981). Finally, the total population may be about three times larger than the earlier Barbour and Humphrey (1982) estimates, or about 3,000 woodrats.

The primary impact of humans on the woodrat is the elimination of its habitat, tropical hardwood hammock, through land development. The absence of the woodrat from apparently suitable habitat in southern Key Largo (Barbour and Humphrey, 1982) indi-

cates that the animal is intolerant of human activity in or adjacent to its habitat. Other impacts arising from human settlement include the introduction of domestic animals, such as cats, and other human-dependent species such as raccoons and oppoussum that may become predators on the woodrat. In addition, the black rat (Rattus rattus), which inevitably accompanies human settlement, may become a competitor with the woodrat (Hersch, 1981). Because of the large acreage that each animal requires, development that divides large hammocks into smaller parcels may render the remaining hammock unsuitable as woodrat habitat, even if the smaller areas are left undisturbed.

3.
PEROMYSCUS GOSSYPINUS ALLAPATICOLA

Key Largo Cotton Mouse

The Key Largo Cotton Mouse is an endemic subspecies of Key Largo. Historically, it occurred throughout that Key but it is now apparently restricted to the northern portion of the island (Brown, 1978). A few cotton mice were introduced onto Lignum Vitae Key in 1970 but there have been no studies to determine if the animal is still present (Brown, 1978).

The Key Largo Cotton Mouse is nocturnal. It is herbivorous, feeding on seeds, fruits and buds of various trees. It builds nests in logs, tree hollows and cavities in the limestone rock (Brown, 1978). Brown (1978) stated that reproduction occurs throughout the year, while Barbour and Humphrey (1982) stated that breeding is highly seasonal.

The Key Largo Cotton Mouse inhabits tropical hardwood hammocks, and has been found in the coastal strand (pickleweed and other salt marsh plants). Barbour and Humphrey (1982) live-trapped cotton mice in two Upper Key Largo hammocks "chosen for their difference in successional age" (pg. 144). In the "mature" hammock they calculated a density of 21.8 cotton mice per hectare (8.8 mice/acre), and in the "intermediate-age" hammock they calculated a density of 1.2 cotton mice per hectare (0.49 mice/acre; Barbour and Humphrey, 1982 (pg. 145). Based on these data Barbour and Humphrey, (1982) concluded that the Key Largo Cotton Mouse is dependent upon mature tropical hardwood hammocks; Brown (1978) also reached this conclusion.

Field work conducted in the spring of 1986 by Humphrey found that density of cotton mice ranged from 3.8 to 19.0 mice per acre. This shows that in prime habitat areas such as mature hammock adjacent to successional areas has far higher densities of mice than earlier estimated. Humphrey (1986) estimated the population on North Key Largo to be approximately 8,000 cotton mice.

The range of the cotton mouse on Key Largo is not completely known, due to its nocturnal habitat, small size and lack

of conspicuous nests. Both Brown (1978) and Barbour and Humphrey (1982) stated that it is currently found only on Upper Key Largo. Presence/absence trapping further south on Key Largo in fall, 1985 and spring, 1986 yielded no cotton mice.

The primary impact of human activities on the Key Largo Cotton Mouse is the outright elimination of its habitat, mature tropical hardwood hammock, for residential and commercial development. As a result of development, large tracts of mature hammock are found on Key Largo only north of the US-1/C-905 intersection. Another impact arising from human settlement is the introduction of domestic pets, such as cats, that may become predators on the cotton mouse.

4.
HERACLIDES ARISTODEMUS PONCEANUS

Schaus Swallowtail Butterfly

The Schaus swallowtail butterfly is endemic to southeastern Florida and the Florida Keys. Historically, the Schaus swallowtail had been collected from mainland areas aound what is now Miami to Lower Matecumbe Key. Its present range is believed to be restricted to Upper Key Largo and the Keys north to Elliot Key (U.S. Fish and Wildlife Service, 1982).

Tropical hardwood hammocks are the exclusive habitat of the Schaus swallowtail butterfly. The eggs are laid almost exclusively on the "host plant" torchwood (Amyris elemifera), although oviposition has been observed on wild lime (Zanthoxylum fagara; Baggett, 1982; Loftus and Kushlan, 1982). Tropical hardwood hammocks and torchwood are found in the Lower Keys and other areas where the Schaus swallowtail is absent. Therefore, there may be other, more subtle, habitat requirements acting on the species that are not presently known (U.S. Fish and Wildlife Service, 1982).

The adult butterflies usually emerge between late April and early June for the flight period that lasts about three (3) weeks (Baggett, 1982). During the flight period mating occurs and the females lay eggs which are the next year's adult population. The flight period is believed to coincide with the beginning of the rainy season when the host plant torchwood has much new leaf growth, which is preferred by the butterfly (Loftus and Kushlan, 1982). The Schaus swallowtail is believed to lay eggs only once per year, which is considered a reproductive disadvantage (Baggett, 1982; Loftus and Kushlan, 1982).

The rarity and short flight period of the Schaus swallowtail mean that comprehensive surveys of potential habitat are logistically impractical. As a result, population estimates remain uncertain. However, it is clear that the range of this species has shrunk, within historic periods, from its previous

coverage of Lower Matecumbe Key to mainland southeast Florida; to its present area of Upper Key Largo and various Keys within Biscayne National Park. The actual numbers have always been very low, with year to year fluctuations (U.S. Fish and Wildlife Service, 1982). In the early 1970's there was apparently an abundance of this species within its current range. However, since that time the population has declined drastically (U.S. Fish and Wildlife Service, 1982). Loftus and Kushlan (1982) reported a lower number in Biscayne National Park in 1981 than in 1979 or 1980; a total of 13 adults were seen in 1979 in the Park. Three larvae, but no adults, were found on Key Largo during surveys in 1980; anonymous collectors reported finding an unspecified number of adults in that year (U.S. Fish and Wildlife Service, 1982). Preliminary results from 1984 surveys indicated that adults were present on the Keys within Biscayne National park, but only one butterfly was found on Key Largo (pers. comm., Robin Fields, U.S. Fish and Wildlife Service, Jacksonville, Florida).

The range of shrinking and population declines of the Schaus swallowtail are attributed to four factors: (1) Widespread aerial application of insecticides by the Monroe County Mosquito Control District; (2) Collecting; (3) Destruction and degradation of tropical hardwood hammocks by land development; and (4) Natural factors (U.S. Fish and Wildlife Service, 1982). The natural factors are drought, which affects the growth of the host plant torchwood, and hurricanes, which have a devastating effect on hammocks and their biota. The Mosquito Control District uses the insecticide "Dibrom" (trade name) for aerial spraying, the insecticide "Baytex" (trade name) for ground-level spraying and the chemical "Altosid" as a larvicide (pers. comm., Mrs. Lois Ryan, Director, Monroe County Mosquito Control District). At present, the District applies these chemicals, as deemed necessary, from the area of the US-1/C-905 intersection and the point where US-1 crosses Jewfish Creek, south and west across Key Largo and the rest of the archipelago to Key West (pers. comm., Mrs. Lois Ryan). The same chemicals are applied by the District to Ocean Reef Club, at the northern tip of Key Largo. At present, the District does not apply these chemicals to the area of Upper Key Largo between US-1 and Ocean Reef Club, because there are no residents in this area demanding mosquito control (pers. comm., Mrs. Lois Ryan). This pattern of mosquito control activities may be one factor in the disappearance of the Schaus swallowtail from its historic range in the Keys, as these insecticides have a devastating effect on this and other non-target species. Destruction of hammocks for land development destroys the Schaus swallowtail habitat and divides the remaining hammocks into isolated parcels to which immigration is unlikely (U.S. Fish and Wildlife Service, 1982). In addition, land development within the habitat increases the demand for mosquito spraying by the new residents; without this wholesale broadcasting of toxic chemicals many people would consider Upper Key Largo (and other Keys) unfit for human habitation. Because of the very low Schaus populations, collecting may pose a major threat in combination with the other factors (U.S. Fish and Wildlife Service, 1982).

5.
Other Species of Concern

DRYMARCHON CORAIS COUPERI

Eastern Indigo Snake

The Eastern indigo snake, a distinct race of this tropical and subtropical species, is found through Florida and southeast Georgia; disjunct populations may be present in South Carolina, Alabama and Mississippi (U.S. Fish and Wildlife Service, 1982). In the Keys, additional records besides those mapped are known throughout Upper Key Largo (north of US-1/C-905 intersection), No Name, Ramrod and Sugarloaf Keys (pers. comm., Paul Moler, Fla. Gam and Freshwater Fish Comm., Gainesville; Steiner et al., 1983). The indigo is a large non-poisonous snake, the average length of adults is 5-6 feet, individuals in excess of 8 feet have been found (Kochman, 1978). The indigo snake is renowned for its gentle disposition towards man and its relatively slow speed.

The indigo snake is carnivorous, preying upon small mammals, birds, lizards, frogs and other snakes, including venomous species (Kochman, 1978). In captive populations mating behavior has been observed from October to March, with 5-12 eggs being laid around May and hatching occurred in August and September (Kochman, 1978; Speake et al., 1979, cited in Steiner et al., 1983).

In the Keys and south Florida the indigo snake utilizes a number of habitats including tropical hardwood hammocks, slash pinelands, beach-berm systems, freshwater wetlands, tidal mangroves, transitional habitats and disturbed lands recolonized by non-native vegetation (Kochmann, 1978; Steiner et al., 1983). It appears to prefer the more upland habitats, but it also has been observed swimming in both fresh and saltwater (Steiner et al., 1983).

In Georgia, Speake, et al. (1979, cited in Steiner et al., 1983) found that average ranges varied seasonally between 241 acres (summer) and 12 acres (winter). Because the range overlap of individual indigo snakes has not been studied, there is no information to estimate population densities per unit area of habitat. Neither the range requirements per individual indigo snake in the Keys nor the range overlap have been studied. However, the large areas utilized by each animal in other areas and the fact that it is a large carnivore would argue that the density per unit area of habitat is quite low.

The population status of indigo snakes in the Keys has not been studied. Throughout Florida, however, there have been declines in the population (U.S. Fish and Wildlife Service, 1982).

The primary threats to the long-term survival of the Eastern indigo snake are loss or degradation of habitat, and collecting for pets (U.S. Fish and Wildlife Service, 1982). The latter threat is due to this species' gentle nature, spectacular size and relatively slow speed. Because individual indigo snakes appear to have large ranges, the survival of reproductively viable populations is dependent upon the maintenance of large, uninterrupted natural areas. Thus, development that divides the habitat of indigo snakes into smaller tracts may effectively eliminate those populations, even if the smaller tracts are maintained intact. Finally, placement of new roads through indigo snake habitat or increased traffic on existing roads may increase mortality rates, as roadkills have contributed to population declines in other locales (U.S. Fish and Wildlife Service, 1982).

COLUMBA LEUCOCEPHALA

White-crowned Pigeon

The white-crowned pigeon is a tropical bird that reaches the northern limit of its distribution in the Florida Keys and the extreme southern edge of the Florida mainland. It also occurs in the Bahamas, Cuba, Puerto Rico, Hispaniola, the West Indies and the Caribbean coast of Central America south of the Yucatan Peninsula (Owre, 1978).

The Florida population of the white-crowned pigeon is migratory between the U.S., the Bahamas and Cuba (Arendt et al., 1979; references therein). The birds arrive in the Keys between March and May, and leave the Keys in late October, although a small proportion of the population remains year-round (Owre, 1978; Arendt et al. 1979, references therein).

The white-crowned pigeon nests in the Florida Keys. Nesting usually occurs on overwash mangrove islands which afford the greatest protection from predators (Owre, 1978). The timing of nesting in other areas is highly variable, occuring from April through September with some birds parenting more than one brood in a year; the availability of food is thought to affect the timing of reproduction (Wiley and Wiley, 1979). Nesting success in one study in Puerto Rico varied between 26% and 68%; predation by red-tailed hawks, corvids (crows, magpies and jays) and rats was the major factor in the mortality of eggs and nestlings (Wiley and Wiley, 1979). In Puerto Rico, egg incubation averages 14 days and nestling period averages 21 days (Wiley and Wiley, 1979). Offspring may mature and nest within one year (Wiley and Wiley, 1979).

The white-crowned pigeon feeds primarily on the fruits and berries of tropical hardwood trees. Dominant food species include poisonwood (Metopium toxiferum), fig (Ficus citrifolia and introduced Ficus spp.) and pigeon plum (Coccoloba diversifolia; Wiley and Wiley, 1979). The birds feed only in the trees,

not on the ground (Wiley and Wiley, 1979). Adult birds make daily flights between larger islands supporting upland vegetation and offshore mangrove islands which are roosting and nesting sites.

The population of this species has been seriously depleted throughout its entire range and this trend is continuing. Arendt et al. (1979) and Wiley (1979) documented the decimation of white-crowned populations throughout the Caribbean, primarily by indiscriminate hunting and widespread habitat destruction. The Dominican Republic on the island of Hispaniola supports the largest concentration of white-crowned pigeons, in that country the birds are being destroyed in large numbers by shooting for sport and food, and removal of the squabs from nests to be fed to cattle and pigs (Arendt et al., 1979). The white-crowned pigeons in Haiti, on the other half of Hispaniola, have already become rare due to hunting and habitat destruction (Arendt et al., 1979). Recent protection of white-crowned pigeons by government regulation in Jamaica and the Bahamas may allow portions of the population to recover (Arendt et al., 1979).

As a result of this widespread decline, the white-crowned populations in the Florida Keys now represent a significant factor in this species' potential for avoiding extinction. Following protection from hunting by state law, the population in this area has recovered to an estimated 10,000-15,000 (Arendt et al., 1979). In addition, the overwash mangrove islands that are the primary nesting and roosting habitat receive a high degree of protection by State and Federal wetland regulations as well as inclusion in Everglades National Park and Wildlife Refuges of the Lower Keys. At present, the primary threat to this species in the Keys is the elimination by land development of its feeding habitat: tropical hardwood hammocks and native slash pinelands. Although white-crowned pigeons are known to feed in areas with some development, they are, on the average, a shy species that flies away from the presence of human beings. Thus, development in hammock or slash pinelands will cause outright elimination of feeding habitat and will discourage the birds from utilizing any trees left in the area following development.

LIGUUS FASCIATUS

Florida Tree Snail

The Florida Tree Snail, Liguus fasciatus Muller, is a large and brilliantly marked species of land snail native to south Florida. Its phenomeanlly beautiful and highly variable color patterns on the shell have led to an intense level of popular and scientific interest in the snail for more than a century. Derived from West Indian snails which it closely resembles, L. fasciatus is truly a tropical species, restricted

to hammocks of tropical hardwood forest in south Florida and the Florida Keys. With the clearing of many of these tropical Florida hammocks for development, and with widespread mosquito control spraying as well as possible overcollecting of the rarer forms, the rich diversity of forms and varieties of this exceptional species in Florida fauna has seemed to be doomed to extinction.

No current summary exists of the present status and extant distribution of this popularly known member of Florida's fauna, and no detailed scientific summary exists of the present distribution compared to the past distribution of the 58 or so named color varieties and forms of this species.

B. Plants

There are a number of plant species living in the hammocks of North Key Largo which are considered as endangered or threatened by the State of Florida. These include lignum vitae, white ironwood, mahogany mistletoe, and several palms, silver palm, Florida thatch palm and brittle thatch palm. See Table III-1 for further detail.

The following charts detail the existence of various plants in the hammocks of North Key Largo. This information was excerpted from The Hardwood Hammocks of the Florida Keys: An Ecological Study (Wiener) published by the National Audubon Society and the Florida Keys Land Trust.

REFERENCES

REFERENCES
NORTH KEY LARGO
HABITAT CONSERVATION PLAN

NATURAL ENVIRONMENT

Alexander, T. R. 1953. Plant succession on Key Largo, Florida involving Pinus caribaea and Quercus virginiana. Quar. Journ. Fla. Acad. Sci.16(3):133-138.

Alexander, T. R. 1958. High hammock vegetation of the southern Florida mainland. Quar. Journ. Fla. Acad. Sci. 21 (4): 294-298.

Alexander, T. R. 1967. A tropical hammock on the Miami (Fla.) limestone: a twenty-five year study. Ecol.48(5): 863-867.

Alexander, T.R. 1974. Evidence of recent sea-level rise derived from ecological studies on Key Largo, Fla., in Environments of South Florida: Present and Past. Miami Geol. Soc. Memoir 2 pp. 219-222.

Alexander, Taylor R. and Alan G. Crook. 1974 Recent Vegetational Changes in South Florida. Pages 61-72 in P.J. Gleason, ed. Environments of South Florida; Present and Past. Miami Geol. Soc. Mem. 2.

Alexander, T. R. and J. D. Dickson. 1972. Vegetational changes in the National Key Deer Refuge, Part II. Quar. Journ. Fla. Acad. Sci. 35:85-96.

Alexander, Taylor R. 1968. Effect of Hurricane Betsy on the southeastern Everglades. Quart. Journ. Fla. Acad. Sci. 30(1) 10-24.

Arendt, W.J., T.A. Vargas Mora, and J.W. Wiley. 1979. White-crowned pigeon: Status rangewide and in the Dominican Republic. Proc. Ann. Conf. S.E. Assoc. Fish and Wildlife Agencies, 33:111-122.

Austin, Daniel F. 1978. Exotic plants and their effects in Southeastern Florida. Environ. Cons.5(1): 25:34.

Avery, G. N. and L. L. Loope, 1980. Endemic Taxa in the flora of South Florida. South Florida Research Center Report T-558. 39 pp.

Baggett, H.D. 1982. Schaus' Swallowtail. Pp. 73-74 in: Franz, R. (ed.). Rare and endangered biota of Florida, Volume six, Invertebrates. University Presses of Florida, Gainesville. 131 pp.

Bak, R.P.M. and J.H.B.W. Elgershuizen. 1976. Patterns of oil-sediment rejection in corals. Marine Biology, Vol. 37. p. 105-113.

Ball, M.C. 1980. Patterns of secondary succession in a mangrove forest in South Florida. Oecologia 44:226-235.

Banner, A.H. 1969. A fresh-water kill on the coral reefs of Hawaii (unpublished ms. draft) data quoted in Odum, H.T., B.J. Copeland and E.A. McMahan. 1974. Coastal Ecological Systems of the United States. Vol. I. Published by The Conservation Fnd., Washington, D.C.

Barbour, D.B., and S.R. Humphrey. 1982. Status and habitat of the Key Largo woodrat and cotton mouse (Neotoma floridana smalli and Peromyscus gossypinus allapaticola). J. Mammol 63: 144-148.

Barbour, T., and G. M. Allen, 1922. The white-tailed deer of eastern United States. J. Mammol. 3:65-78.

Bass, N.M. 1969. Petrography and ages of crystalline basement rock of Florida -- some extrapolations. Mem. Am. Assn. Petrol. Geol. 11-pp. 283-310.

Beard, J. S. 1955. The classification of tropical American vegetation types. Ecology 36(1): 89-100.

Birkeland, C., A.A. Reimer, and J.R. Young. 1976. Survey of marine communities in Panama and experiments with oil: Office of Research and Development, Environmental Research Laboratory, EPA-600/3-76-028, Narragansett, R.I., 117 pp.

Bradley, J.T. 1972. Climate of Florida, in Climate of the States. Environmental Data Service #60-8. Silver Sprg. Mal.

Brooks, H.K. 1973. Geological oceanography, in A summary of the Knowledge of the Eastern Gulf of Mexico. IIE 1-18.

Brooks, H.K. 1982. Geologic Map of Florida accompanied by physiographic divisions, State of Florida, Coop Extension Service, IFAS, Univ. of Fla. G-5M-82.

Brown, L.N., 1978. Key Largo Woodrat. Pp. 11-12 in: Layne, J.N. (ed.). Rare and endangered biota of Florida, Volume One, Mammals. Univ. Presses of Florida, Gainesville 52 pp.

Brown, L.N. 1978. Key Largo cotton mouse. Pp. 10-11 in: J.N. Layne (ed.). Rare and endangered biota of Florida, Vol. One, Mammals. Univ. Presses of Florida, Gainesville, 52 pp.

Campbell, H.W. 1978. Miami black-headed snake. Pp. 45-46 in: McDiarmid, R.W. (ed.). Rare and endangered biota of Florida, Volume Three, Amphibians and reptiles. Univ Presses of Florida. Gainesville. 74 pp.

CH_2M Hill. "1983 Biological Monitoring Results, Stock Island Power Plant." (April, 1984).

Chesher, Richard. "Environmental Impact Assessment, City of Key West Sanitary Landfill Project." (Dec., 1973).

Chesher, R.H. 1974. Canal survey: Florida Keys. A report for the Society for Correlation of Progress and Environment pp. 1-173.

Clark, John R. 1977. Coastal ecosystem management. New York: John Wiley & Sons.

Cowardin, Lewis M., V. Carter, F. C. Golet and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Office of Biol. Serv., Wash: FWS/OBS-79/31.

Craighead, Frank C. and Vernon C. Gilbert, 1962. The effects of Hurricane Donna on the vegetation of southern Florida. Quart. journ. Fla. Acad. Sci. 25(1):1-28.

Craighead, Frank C., Sr. 1971. The trees of South Florida: Vol. I Coral Gables: University of Miami Press.

Craighead, F. C. 1974. Hammocks of South Florida. Pages 53-60 in Gleason, P. J., ed., 1974. Environments of South Florida, Present and Past. Memo 2. Miami Geological Society, Coral Gables, Fla.

Dames and Moore, 1978. Florida sulfur oxides study #2 -- dispersion meteorology and climatology 3 Vol. Prep. for Fla. sulfur oxide study Inc. Dames and Moore, Atlanta, Georgia.

Davis, J. H. 1940. The Ecology and Geologic Role of Mangroves in Florida. Carnegie Inst., Wash. Publ. 517. Tortugas Lab. Pap. 32:303-412.

Davis, J. H., Jr. 1943. The natural features of southern Florida. Fla.Geol.Surv.Bull.25. State of Florida, Dept. of Conservation, Tallahassee. 311 pp.

Deisler, J.E. 1982. Stock Island tree snail. Pp. 8-9 in: Franz, R. (ed.). Rare and endangered biota of Florida, Volume Six, Invertebrates. Univ. Presses of Florida. Gainesville. 131 pp.

Diaz-Piferrer, M. 1962. The effects of an oil spill on the shore of Guanica, Puerto Rico. (Abstr.) Ass. Island Mar. Labs., 4th Meeting Caraibish Marien Biologisch Inst. Curacao, Neth. Aut. (also Deep-Sea Res. 11(5); 855-856).

DiSalvo, Louis H. and H.T. Odum. 1974. Coral Reefs in Coastal ecological systems of the United States. Vol. I. edited by H.T. Odum, B.J. Copeland, and E.A. McMahan, publ. by The Conservation Fndn., Wash., D.C.

Dubar, J.R. 1974. Summary of the Neogena stratigraphy of southern Florida in Post Miocene Stratigraphy Central and Southern Atlantic Coastal Plan. Utah Stat. Univ. Press. Logan.

Enos, P. 1977. Quarternary sedimentation in South Florida. Part I. Holocene sediment accumulations of the South Florida shelf margin. Geol. Soc. Am. Mem. 147:1-130.

Environmental Protection Agency, Surveyance and Analysis Division. "Hydrographic, Water Quality and Biological Studies of the Joseph Harrison Canal System." (April, 1980).

Ewel, John J., et al. 1982. Schinus in Successional Ecosystems of Everglades National Park, Report T-676. South Florida Research Center.

Fairbridge, R.W. 1974. The Holocene sea level record in South Fla. in Environments of South Florida: Present and Past. Miami Geol. Soc. Memoir 2 pp. 223-232.

Fishelson, L. 1973. Ecology of coral reefs in the Gulf of Agaba (Red Sea) influenced by pollution: Oecologica, Vo. 12, p. 55-67.

Fisk, E.J., 1978. Least tern. Pp. 40-43 in: Kale, H.W. II (ed.). Rare and endangered biota of Florida, Volume Two, Birds. Univ. Presses of Florida. Gainesville, 121 pp.

Florida Coastal Coordinating Council. 1974. Florida Keys Coastal Zone Management Study. Fla. Dept. Nat. Res.

Florida, Dept. of Pollution Control. "Survey of Water Quality in Waterways and Canals of the Florida Keys." (April, 1973).

Florida, Dept. of Environmental Regulation. "Report to the Environmental Reg. Comm. - Proposed Designation of the Waters of Fl. Keys as Outstanding Florida Waters. Vol. I and II." (1985).

Florida, Dept. of Env. Reg. "Work Plan: 205(j) Keys Monitoring Study." South Florida District, Marathon Branch Office. (Oct. 1983).

Florida Keys, Dept. of Natural Resources." Monroe Cty. Aquatic Preserve Management Plan." (Dec. 1984).

Florida, Dept. of Pollution Control. Review of Chesher Report entitled 'Canal Survey - Fl. Keys.' by State Agencies and University Personnel (1974).

Florida Keys Aqueduct Authority." Environmental Monitoring of Buttonwood Sound in Area of the Rock Harbor Reserve Osmosis Plant, Baseline Benthic Samples."

Fogarty, M.J. 1978. American alligator. Pp. 65-67 in: McDiarmid, R.W. (ed.). Rare and endangered biota of Florida, Volume Three, Amphibians and reptiles. Univ. Presses of Florida. Gainesville. 74 pp.

Furley, P.A. and W. W. Newey. 1979. Variations in Plant Communities with Topography over Tropical Limestone Soils. Jour. Biogeog. 6:1-15.

Gentry, R.C., 1973. Hurricanes in South Florida in Environments of South Florida Present and Past. Miami Geol. Soc. Memo 2 pp. 73-81.

Gleason, P. J. and W. Spackman, Jr. 1974. Calcareous periphyton and Water Chemistry in the Everglades. Pages 146-181 in P. J. Gleason, ed. Environments of South Florida: Present and Past Miami Geol. Soc. Mem.2

Glynn, P.W. 1968. Mass mortalities of echinoids and other reef flat organisms coincident with midday, low water exposures in Puerto Rico. Mar. Biol. 1(3):226-243.

Glynn, P.W., L.R. Almodovar and J.H. Gonzales. 1964. Effects of Hurricane Edith on marine life in LaParguera, Puerto Rico. Carib. J. Sci. 4 (2/3): 335-345.

Goodyear, Numi. "Results of a study of Key Largo Woodrats and Cotton Mice: Phase I", unpubl. ms., 1985

Gross, J.K. 1977. Oceanography: a view of the Earth. Prentice Hall 229-254.

Hall, E. R. and K. R. Kelson. 1959. The mammals of North America. The Ronald Press Co., New York 2:685.

Hanson, C.E. 1980. Freshwater resources of Big Pine Key, Fla. L.S.G.S. Open File Report 80-447.

Hartman, D.S. 1978. West Indian Manatee. Pp. 27-30 in: Layne J.N. (ed.). Rare and endangered biota of Florida, Volume One, Mammals, Univ. Presses of Florida, Gainesville. 52 pp.

Helbring, R.J., Kent, S. and Lawliss, D. "Effects of an Offshore Navigational Access Channel on the Marine Benthic Community."

Hersch, S.L. 1978. Ecology of the Key Largo woodrat (Neotoma floridana smalli). Unpunl. M.S. thesis, Univ. of Miami. 106 pp.

Hoffmeister, J.E. 1974. Land from the sea. University of Miami Press. Coral Gables, Florida pp. 1-143.

Hoffmeister, J.E. et al. 1967. Miami limestone of Florida and its recent Bahamian counterpart. Geol. Soc. Am. Bull. 78 pp. 175-190.

Hoffmesiter, J.E. and H.G. Multer. 1968. Geology and origin of the Florida Keys. Geol. Soc. Am. Bull. 79 pp. 1487-1502.

Hofstetter, Ronald,, H. 1974. The Effect of Fire on the Pineland and Sawgrass Communities of Southern Florida Pages 201-212 in P.J. Gleason, ed. Environments of South Florida; Present and Past. Miami Geol. Soc. Mem. 2.

Howard, Richard A. 1950. Vegetation of the Bimini Island Group, Bahamas, B.W.I. Ecological Monographs 20(4):318-349.

Hubell, S.P. 1979. Tree dispersion, abundance and diversity in a tropical dry forest. Science 203:1299-1309.

Jaap, W.C. 1982. The ecology of the coral reefs of South Florida: a community profile. U.S. Fish and Wildlife Service, Office of Biol. Svc., Wash., D.C. FWS/OBS-82/02.

Jacobsen, Terri. 1983. Crocodilians and islands: status of the American Alligator and the American Crocodile in the lower Florida Keys. Fla.Field Nat. 11(1):1-24.

Jones, J.A. 1977. Morphology and development of southeastern Florida patch reefs. Pages 231-235 in Proceedings: 3rd International Coral Reef Symposium. Rosensteil School of Marine & Atmospheric Science. Univ. of Miami, Miami Fla.

Jordan, C.L. 1973. Climate in A Summary of the Knowledge of the Eastern Gulf of Mexico, State University System of Florida Institute of Oceanography IIA 1-22.

Kaplan, E.H. 1962. A field guide to coral reefs. Houghton Mifflin Co. Boston, Mass. 289 pp.

Kissling, D.L. 1977. Coral reefs in the lower Florida Keys: a preliminary report. Pages 209-215 in H.G. Multer, ed. Field Guide to some carbonate rock environments: Florida Keys and western Bahamas. Kendall/Hunt Publ. Co., Dubuque, Iowa.

Klein, H. 1970. Preliminary evaluation of availability of potable water on Elliott Key, Dade Co., Fla. U.S.G.S. Open File Report 70-010.

Kochman, H.I. 1978. Eastern indigo snake. Pp. 68-69 in: McDiarmid, R.W. (ed.). Rare and endangered biota of Florida, Volume Three, Amphibians and reptiles. Univ. Presses of Florida. Gainesville. 74 pp.

Kushlan, J.A., J.C. Ogden and A.L. Higer. 1975. Relation of water level and fish availability to wood stork reproduction in the southern Everglades, Florida. U.S. Dept. of the Interior, Geological Survey. Open File Report 75-434. Tallahassee. 56 pp.

Layne, J. N. 1974. The land mammals of South Florida. p. 386-413 in Gleason, P.J., ed. 1974. Environments of South Florida, Present and Past. Memoir 2. Miami Geological Soc., Coral Gables, Fla.

Lazell, James D., Jr. 1984. A new marsh rabbit (Sylvilagus palustris) from Florida's Lower Keys. J. Mamm. 65(1):26-33.

Lazell, J.D. Jr. Distribution and rarity of the Key ringneck snake, Diadophis punctatus aricus. Unpubl. manuscript 9 pp. plus figures.

Loftus, W.F. and J.A. Kushlan 1982. The status of the Schaus' Swallowtail and the Bahama Swallowtail butterflies in Biscayne National Park. South Florida Research Center Report M-649. 18 pp.

Loveless, A. R. 1983. Principles of Plant Biology for the Tropics. Longman Group Ltd., New York 532 pp.

Lugo, A.E. and S.C. Snedaker. 1974. The Ecology of Mangroves. Ann. Rev. Ecol. Syst. 5:39-64.

Lund, F. 1978. Atlantic loggerhead. Pp. 35-36 in: McDiarmid, R.W. (ed.). Rare and endangered biota of Florida, Volume Three, Amphibians and reptiles. University Presses of Florida, Gainesville. 74 pp.

Lund, F. 1978. Atlantic leatherback turtle. Pp. 54-55 in: McDiarmid, R.W. (ed.) Rare and endangered biota of Florida, Volume Three, Amphibians and reptiles. University Presses of Florida, Gainesville, 74 pp.

Lund, F. 1978. Atlantic ridley turtle. Pp. 25-26 in: McDiarmid, R.W. (ed.). Rare and endangered biota of Florida, Volume Three, Amphibians and reptiles. University Presses of Florida, Gainesville. 74 pp.

Lund, F. 1978. Atlantic Green Turtle. Pp. 23-24 in: McDiarmid, R.W. (ed.). Rare and Endangered Biota of Florida, Volume Three, Amphibians and Reptiles. Univ. Presses of Florida, Gainesville, 74 pp.

Lund, F. 1978. Atlantic Hawksbill. Pp. 24-25 in: McDiarmid, R.W. (ed.). Rare and endangered biota of Florida, Volume Three, Amphibian and reptiles. Univ. Presses of Florida, Gainesville, 74 pp.

Marmer, H.A. 1954. Tides and sea level in the Gulf of Mexico. U.S. Fish Wildlife Serv. Fish. Bull. 55(89) 1:101-118.

Marszalek, D.S., G. Babashoff, M.R. Noel, and D.R. Worley. 1977. Reef distribution in South Florida. Pages 223-230 in D.L. Taylor, ed. Proceedings: 3rd International Coral Reef Symposium, Vol. 2. Rosenstiel School of Marine and Atmospheric Science. Univ. of Miami, Miami, Fla.

Mayer, A.G. 1914. The effects of temperature upon tropical marine animals. Pap. Tortugas Lab. 6:1-24.

McNulty, J. K. 1970. Studies in tropical oceanography No. 9: effects of abatement of domestic sewage pollution on the benthos volumes of zooplankton and the fouling organisms of Biscayne Bay, Florida. Stud. Trop. Oceanogr. Inst. Mar. Atmos. Sci. Univ. Miami. 107 pp.

McNulty, J. K., W. N. Lindall, Jr., and J. E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study, Florida, Phase I: Area description. National Ocean.Atmos. Admin.Tech.Tep.Int.Mar.Fish.Serv.Circ. 368:1-126.

Miller, A. 1971. Meteorology. Merrill and Co., Columbus, Ohio 153 pp.

Multer, H.G., ed. 1977. Field guide to some carbonate rock environments: Florida Keys and western Bahamas. Kendall/Hunt Publ. Co., Dubuque, Iowa.

Muscatine, L. 1967. Glycerol excretion by symbiotic algae from corals and Tridacna and its control by the host. Science 156 (3774): 516-519.

Niering, William A. and R. S. Warren. 1977. Salt marshes. pp. 697-702 in Clark, J., ed. Coastal ecosystem management, New York, John Wiley & Sons.

Odell, D. K. 1976. Distribution and abundance of marine mammals in south Florida: preliminary results. Pages 203-212 in A. Thorbaug, ed. Biscayne Bay: past/present/future. Biscayne Bay Symposium 1, Univ. Miami Sea Grant Spec.Rep.5.

Odell, D. K. 1979. Distribution and abundance of marine mammals in the waters of the Everglades National Park. Pages 673-678 in R.M. Linn, ed. Proceedings of the first conference on scientific research in the national parks. Vol. 1 U.S. Dept. Int.Nat'l.Park.Serv.Travis.Proc.Ser.No.5.

Odum, W. D., C. D. McIvor, and T. G. Smith. 1982. The Ecology of the Mangroves of South Florida: A Community Profile. U.S. Fish and Wildlife Serv., Office of Biol. Serv., Wash., D. C. FWS/OBS-81/24.

Ogden, J.C. 1978. Status and nesting biology of the American crocodile, Crocodylus acutus, (Reptilia, Crocodilidae) in Florida. J. Herptol 12(2): 183-196.

Ogden, J.C. 1978. American Crocodile. Pg. 21-22 in: McDiamird, R.W. (ed.). Rare and endangered biota of Florida, Volume Three, Amphibians and reptiles. Univ. Presses of Florida, Gainesville. 74 pp.

Ogden, J.C. 1978. Wood Stork. Pp. 3-4 in: Kale, H.W. II (ed.). Rare and endangered biota of Florida, Volume Two, Birds, Univ. Presses of Florida, Gainesville, 121 pp.

Ogden, J.C., J.A. Kushlan and J. T. Tilmant. 1978. The food habitats and nesting success of wood storks in Everglades National Park 1974. U.S. Dept. of the Interior, National Park Service Natural Resources Rpt. No. 16, Washington, D.C. 25 pp.

Olmstead, I., and L. L. Loope. 1984. Plant communities of Everglades National Park. p. 167-184 in Gleason, P. J. ed., 1984. Environments of South Florida, Present and Past II. Miami Geol.Soc., Coral Gables, Fla.

Olmstead, I. D., L. L. Loope and R. P. Russell. 1981. Vegetation of the southern coastal region of Everglades National Park between Flamingo and Joe Bay. Report T-620, South Florida Research Center, ENP.

Owre, O.T. 1978. White-crowned pigeon. Pp. 43-45 in: Kale, H.W. II (ed.). Rare and endangered biota of Florida, Volume Two, Birds. Univ. Presses of Florida. Gainesville. 121 pp.

Parker, G.G., et al. 1955. Water resources of southeastern Florida with special references to the geology and groundwater of the Miami area. U.S.G.S. Water Supply Paper 1255.

Parker, G.G. and C.W. Cooke. 1944. Late Cenozoic geology of Southern Florida with a discussion of the groundwater. Fla. Bur. Geol. #27.

Patriquin, D. G. 1975. "Migration" of blowouts in seagrass beds at Barbados and Caribbean, West Indies, and its ecological and geological implications. Aquat.Bot. 1:163-189.

Paulson, D.R. 1968. Variations in some snakes from the Florida Keys. Quart. J. Florida Aca. Sci., 29(4): 295-308

Porras, L. and L.D. Wilson. 1979. New distributional records for Tantilla oolitica Telford (Reptilia, Serpentes, Colubridae) from the Florida Keys. J. Herpetol., 13(2): 218-220.

Provost, M.W. 1973. Mean high water mark and use of tidelands in Florida. Fla. Scientist Vol. #36 (1) 50-66.

Puri, H.S. and R.O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. Fla. Geol. Surv. Special Pub. #5.

Reimer, A.A. 1975. Effects of crude oil on the feeding behavior of the zoanthic, Polythoa variabilis, Environ.

Robertson, W. B., Jr. 1955. An analysis of the breeding bird populations of tropical Florida in relation to the vegetation. Ph.D. thesis, Univ. Illinois 599 pp.

Robertson, W. B., Jr. and J. Kushlan. 1974. The south Florida arifauna. pp. 414-452 in Gleason, P. J. ed., 1974. Environments of South Florida, Present and Past. Memo 2. Miami Geological Society, Coral Gables, Florida.

Robertson, W.B. 1978. Roseate tern. Pp. 39-40 in: Kale, H.W. II (ed.). Rare and endangered biota of Florida, Volume Two, Birds. Univ. Presses of Florida. Gainesvill. 121 pp.

Robertson, W.B. Jr. 1978. Southern Bald Eagle. Pp. 27-30 in: Kale, H.W. II (ed.). Rare and endangered biota of Florida, Volume Two, Birds. University Presses of Florida, Gainesville. 121 pp.

Roseneu, et al. 1977. Springs of Florida. Fla. DNR Bur. Geol. Bull. #31 revised.

Schomer, N. Scott and Richard D. Drew. 1982. An ecological characterization of the lower everglades, Florida Bay and the Florida Keys. Report prepared by Fla. DER for U.S.F.W.S. and Bureau of Land Management. FWS/OBS-82/58.1. 246 pp.

Schreiber, R.W. 1978. Eastern Brown Pelican. Pp. 23-25 in: Kale, H.W. II (ed.). Rare and endangered biota of Florida, Volume Two, Birds. Univ. Presses of Florida, Gainesville, 121 pp.

Schwartz, A. 1952. The land mammals of southern Florida and upper Florida Keys. Unpubl. dissert., Univ. Michigan. 180 pp.

Sellars, E.H. 1909. Geologic section across the Everglades, Florida. Fla. Geol. Surv. Annual Report 12 pp. 67-76.

Shurbet, D.H. 1968. Upper mantle structure beneath the margin of the Gulf of Mexico, Geol. Soc. Am. Bull. 79 pp. 1647-1650.

Snyder, H. 1978. Peregrine falcon. Pp. 7-9 in: Kale H.W. II (ed.). Rare and endangered biota of Florida, Volume Two, Birds. Univ. Presses of Florida. Gainesville. 121 pp.

Speake, D.W., J.A. McGlinch, and T.R. Colvin. 1979. Ecology and management of the eastern indigo snake in southern Florida national parks and vicinity. So. Fla. Res. Cntr. (Everglades Nat. Park), Report #SFRC-83/01. 25 pp.

Steiner, T.M., O.L. Bass, Jr. and J.A. Kushlan. 1983. Status of the eastern indigo snake in southern Florida national parks and vicinity. So. Fla. Res. Cntr. (Everglades Nat. Park), Report #SFRC-83/01. 25 pp.

Stringfield, V.T. 1966. Artesian water in tertiary limestone in the Southeastern States. U.S.G.S. Professional Paper 517. pp. 1-226.

Stursa, Mary Lou. 1973. Environmental quality problems. pp. VI-1 through VI-17 in A Summary of Knowledge of the Eastern Gulf of Mexico. State Univ. System of Fla. Institute of Oceanography. St. Petersburg, Fla.

Taylor, J. L. and C. H. Saloman, 1968. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida. U.S. Fish Wildl.Serv.Fish.Bull, 67(2): 213-241.

Taylor, J. L., C. H. Saloman, and K. W. Priest, Jr. 1973. Harvest and regrowth of turtle grass (Thalassia testudinum) in Tampa Bay, Florida. U.S. Natl.Mar.Fish.Serv.Fish.Bull. 71(1): 145-148.

Thomas, T.M. 1974. A detailed analysis of climatological and hydrological records of South Florida with references to man's influences upon ecosystem influence in Environments of South Fla. Miami Geol. Soc. Memo 2. pp. 82-122.

U. S. Department of the Interior. 1979. Loggerhead sea turtle. U.S. Fish and Wildlife Service unpubl. mimeo. 3 pp.

U.S. Fish and Wildlife Service. 1979. Eastern peregrine falcon recovery plan. 147 pp.

U.S. Fish and Wildlife Service. 1982. Eastern indigo snake recovery plan. U.S. Fish and Wildlife Service, Atlanta, GA 23 pp.

U.S. Fish and Wildlife Service. Schaus' Swallowtail Butterfly recovery plan. U.S. Fish and Wildlife Service, Atlanta, Ga 57 pp.

U.S. Fish and Wildlife Service. 1980. West Indian Manatee recovery plan. U.S. Fish and Wildlife Service. 35 pp.

U. S. Fish and Wildlife Service. 1984. American crocodile recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 37 pp.

U.S. Dept. of Interior. 1981. Eastern Brown Pelican. Unpubl. mimeo. 4 pp.

U.S. Fish and Wildlife Service. 1979 Recovery Plan for the Eastern brown pelican (Pelecanus occidentalis carolinensis). 44 pp.

U. S. Department of the Interior. 1977. Leatherback turtle. U.S. Fish and Wildlife Serivce, Unpubl. mimeo. 4 pp.

Wainwright, S.A. 1967. Diurnal activity of hermatypic gorgonians. Nature 216:1041.

Wang, F.C. 1978. Impacts of Surface Drainage on Groundwater Hydraulics. Paper presented to the 14th American Water Resources Conferences, Lake Buena Vista, Fl.

Weiner, A.H. 1979. The Hardwood Hammocks of the Florida Keys: An Ecological Study. National Audubon Society and Florida Keys Land Trust.

White, W.A. 1970. The geomorphology of the Florida Peninsula. Fla. Bur. Geol. Bull. 51.

Wiley, J.W. and B.N. Wiley. 1979. The biology of the white-crowned pigeon. Wildl. Monogr. No. 64, 54 Pp.

Wiley, J.W. 1979. The white-crowned pigeon in Puerto Rico: status, distribution and movements. J. Wildl. Manage., 43(2): 402-413.

Williams, L.E. and L.L. Martin, 1970. Nesting populations of brown pelicans in Florida. Proc. Southeast. Game and Fish Commissioners. 24: 154-169.

Williams, S.L. 1981. Caulerpa cupressoides: the relationship of the uptake of sediment ammonium and of algae decomposition for seagrass bed development. Ph.D. Dissertation, University of Maryland.

Zieman, J. C. 1975. Tropical sea grass ecosystems and pollution. Chapter 4 in E.J.F. Wood and R.E.Johannes, eds. Tropical marine pollution, Elsevier Oceanography Series 12. Elsevier Publ.Co., New York.

Zieman, J. C. and E. J. F. Wood. 1975. Effects of thermal pollution on tropical-type estuaries, with emphasis on Biscayne Bay, Florida. Chapter 5 in E. J. F. Wood and R. E. Johannes, eds. Tropical Oceanography Series 12.

Zieman, Joseph C. 1982. The Ecology of the Seagrasses of South Florida: A Community Profile. U.S. Fish and Wildlife Services, Office of Biological Services, Washington, C.S. FWS/OBS-82/25. 158 pp.

EXISTING USES

Environmental Effects Laboratory. 1978. Preliminary Guide to Wetlands of Peninsular Florida - Major Associations and Communities Identified. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss. Technical report Y-78-2. 66 pages (plus appendices).

Florida Coastal Coordinating Council. 1974. Florida Keys Coastal Zone Management Study. Fla. Dept. of Natural Resources. Tallahassee, Florida. 138 pages.

Lugo, A.E. and S.C. Snedaker. 1974. The Ecology of Mangroves. Annual Review of Ecology and Systematics. 5:39-64.

Odum, W.E., C.C. McIvor and T.J. Smith, III. 1982. The Ecology of the Mangroves of South Florida: A Community Profile. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-81/24. 144 pages.

PLATTED LANDS

Recorded Plat Volume, Real Estate Atlas of Monroe County, Florida, Real Estate Data, Inc., 1984.

Strip Map Volume, Nineteenth Edition published 1983 and Twentieth Edition published 1984, Real Estate Atlas of Monroe County, Florida, Real Estate Data, Inc.

Aerial/Map Volume, Nineteenth Edition published 1983 and Twentieth Edition published 1984, Real Estate Atlas of Monroe County, Florida, Real Estate Data, Inc.

Plat Maps showing Water Main Distribution Lines, Florida Keys Aqueduct Authority, 1984.

Plat Maps showing Electric Transmission Lines, City Electric, 1984.

AICUZ Land Acquisition Map, Key West Naval Air Station, Key West, Florida, 1984.

Land Use, Cover and Forms Classification System, a technical Manual, State of Florida, Department of Transportation, State Topographic Office, Remote Sensing Center, May, 1981.

Subdivision Map on a base map at a scale of 1" = 200'.

Subdivision Listing showing plat, locational and planning area references. The list is available in alphabetical or planning area order.

Platted Lands Survey, February, 1985.

Planning Areas Summaries with total lots by land use type and total acreage by land use type and a brief description of each land use type.

County Summary of Subdivided Lands which provides totals for the following categories: residential lots, disturbed lots, disturbed lots, upland lots, wetland lots and other lots. Single Family % Developed and lot size, mean, standard deviation and median lot size is also given. A weighted average for single family lot size is also given for a better indicator of the true mean lot size in the County.

Report or Summary of the Platted Lands Survey is also available. The number of developed, improved and vacant, and unimproved and vacant lots are estimated by lot size for each subdivision.

A summary table of the rePort is available. The summary provides the number of developed lots, the number of improved and vacant lots and the number of vacant and unimproved lots by lot size for the upper, middle, lower keys and a summation of the county totals.

AIRPORTS

Upper Keys Airport Site Selection Study, BR & R Associates, Inc. and Post, Buckley, Schuh & Jernigan, Inc. (March, 1983)

Interviews with Monroe County Airport officials, July, August, and December, 1984.

POTABLE WATER

Accountants Report and Financial Statements, Florida Keys Aqueduct Authority, Parks, Bishop & Hutchings, CPAs (Sept. 1983).

Engineering and Financial Report for the Florida Keys Aqueduct Authority, Black, Crow and Eidness, Inc. (May, 1976).

Florida Keys Aqueduct Authority Transmission Main Analysis, Ray L. Hart & Associates, Inc. (1984)

"Florida Keys Aqueduct Authority and Monroe County Florida Application for Water Permit Use," Ray L. Hart and Associates, Inc. (February 1984).

Summary Report of Alternative Water Supply Services and Transmission Options, James M. Montgomery Consulting Engineers, Inc. (May 1975).

Interviews with Florida Keys Aqueduct Authority officials in May, June and July, 1984.

WASTEWATER TREATMENT

"Estimated Daily Sewage Flows by Type of Establishment," FDER, Marathon (1982)

"Florida Keys Coastal Zone Management Study," State of Florida Department of Natural Resources Coastal Coordinating Council, (June 1974).

Monroe County Services & Utility Element (1978).

"Technical Information Memorandum on Estimated Sewage Flows," FDER, Marathon (1983)

"Wastewater Treatment Facilities Monroe County," FDER, Marathon (1984)

SOLID WASTE DISPOSAL

Letter to Board of County Commissioners from Charles P. Aguero Re: Report on the District for fiscal year 1982 (March 11, 1983)

Letter to Board of County Commissioners from Charles Aguero Re: Volume Reduction Plans, Current and Projected Loads (March 11, 1982)

Letter to Alan Lesster, Director Monroe County Planning and Zoning Department, from Charles Aguero Re: Solid Waste Generation Per Capita (September 24, 1982)

Letter from Dr. James W. May, Chief Bureau of Land and Water Management, Department of Community Affairs, Re: Provision for Solid Waste Service for Major Developments in Upper Key Largo.

Memo to Charles Aguero from Jeff Doyle, Director of Planning and Zoning Re: Key Largo volume reduction plant and landfill current and projected loan (Sept. 19, 1983).

Preliminary Draft of Monroe County Comprehensive Plan, Subelement on Solid Waste, CH2M Hill (June, 1978).

Interviews with Monroe County Municipal Service District officials.

ELECTRICAL FACILITIES

Comprehensive Engineering Report FYE September 30, 1982 to May 31, 1983, C.E. Maguire Inc., 1983.

Electric Refunding Revenue Bonds, series 1984, C.E. Maguire, Inc. (1984).

Florida Keys Transmission and Feasibility Study to Utility Board of the City of Key West, Lemco Engineers, Inc. and Souther Engineering (November 1983).

Interviews with Florida Keys Electric Cooperative Association officials in August and November, 1984.

POLICE FACILITIES

David Plummer & Associates, Inc. Upper Keys Traffic Study, (1984).

Institute of Police Traffic Management The Police Executive and New Growth (1983).

National Sheriff's Association, Analysis of Personnel Requirements of the Monroe County Sheriff's Department, (1981).

Orange County, Florida Five Year Law Enforcement Manpower Allocation Plan, (1983).

Post, Buckley, Schuh & Jernigan, Inc., Monroe County Jail/Government Planning Study, (1983).

State of Florida, Department of Law Enforcement, Crime in Florida, (1983, 1982, 1980).

U. S. Department of Justice, Sourcebook of Criminal Justice Statistics, (1980).

Interviews with Sheriff's Department officials in July, August, and November, 1984.

FIRE PROTECTION AND EMERGENCY MEDICAL SERVICES

Emergency Medical Services Plan for Monroe County, prepared by Emergency Medical Services Task Force (August, 1975)

Monroe County Code

Florida Fire Prevention Code, State Treasurer and Fire Marshall (1982).

LIBRARY FACILITIES

Florida Department of State. Division of Library Services. 1983 Florida Library Directory with Statistics. Tallahassee, Florida, Florida Department of State, 1983.

Florida Library Association. Florida Standards for Public Library Service. Tallahassee, FL., Fla., 1974.

Florida Library Association. Florida Guidelines for Public Library Service. Unpublished draft. Tallahassee, Fl., Fla., 1982.

Illinois Library Association. Avenues to Excellence; Standards for Illinois Public Libraries. Chicago, Ill. 1983.

Interim Standards for Small Public Libraries: Guidelines toward Achieving the Goals of Public Library Service. Public Library Association, 1962.

Palmour, Vernon E., Marcia Bellassai, and Nancy V. DeWath. A Planning Process for Public Libraries, Chicago, Ill. 1980

Palmour, Vernon E. A Planning Process for Public Libraries. American Library Association, 1980.

Public Library Association. Goals, Guidelines, and Standards Committee. The Public Library Mission Statement and Its Imperatives for Service. American Library Association, 1979.

Wheeler, Joseph Lewis. Wheeler and Goldhor's practical administration of Public Libraries. Harper Row, 1981.

Zweizig, Douglas and Eleanor Jo Rodger. Output Measures for Public Libraries: A Manual of Standardized Procedures. Chicago, Ill., 1982.

EDUCATIONAL FACILITIES

Educational Plant Survey Monroe County Schools, Florida Department of Education (May, 1982)

Educational Facilities Rules of Florida State Board of Education Public Schools and Community Colleges, Chapter 6A-Z, Fla. Admin. Code

Florida Inventory of School Houses

"Weekly Enrollment for Public Schools in Monroe County," K. Highsmith (1984)

"Projected Enrollment for Coral Shores High School, Key Largo Elementary, and Plantation Elementary," K. Highsmith (1984)

"Memorandum to Superintendent of Schools, District School Board of Monroe County," (1983-84 District Summary Budget)

HURRICANE PROTECTION

Structural Report on Hurricane Shelters, (1982) Office of Civil Defense

Technical Data Report: Lower Southeast Florida Hurricane Evacuation Study, Post, Buckley, Schuh & Jernigan (June, 1983)

The Monroe County Hurricane Emergency Plan, Monroe County Office of Civil Defense (1984)

PARKS AND WILDLIFE REFUGES

Monroe County Public Works Listing of Parks and Other Public Lands Owned by the County

Monroe County Comprehensive Plan, Park and Recreation Element (1977)

Outdoor Recreation in Florida (1981)

School Board of Monroe County Listing of Properties (1983)

APPENDIX A

RESULTS OF A STUDY OF KEY LARGO WOODRATS AND COTTON MICE: PHASE I, SPRING AND SUMMER 1985

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INTRODUCTION

During May and June, 1985, portions of Key Largo were surveyed for Key Largo woodrats, Neotoma floridana smalli, and Key Largo cotton mice, Peromyscus gossypinus allapaticola. Trapping was conducted in 15 hammocks, mapped in the Florida Keys Hardwood Hammock Atlas (Ruttenber and Weiner, 1977), and described by Weiner (1979), to determine presence or absence of both endangered species. Trapping occurred on 45 sites within these hammocks.

Radiotelemetry was used, augmented by a new method of tracking small mammals, dust capsule tracking, to gain information on habitat use and home range size. These methods were also used to evaluate the extent of association of woodrats with stick nests. Results of both the telemetry and dust capsule tracking, and the trapping program indicated habitat preferences for each species. Based on these results preliminary recommendations can be made regarding land conservation.

In this report I will outline the methodology, give brief descriptions of the trapping sites and summarize trapping results, sumarize and discuss results of the telemetry/dust capsule tracking study, and discuss the implications of the apparent habitat use in evaluating habitat quality.

METHODS

Presence/Absence Determination

Trap-lines, consisting of 10 to 20 H.B. Sherman live traps (model LFAGTD - 7.5 by 8.5 by 22 cm), were set at 44 sites in 14 hammocks north of the US 1/S-905 split, and one hammock to the south. One trap-line was set for approximately every 25 acres under survey; additional lines were set in some smaller parcels if they were geographically separated from the main hammock or if radiotelemetry was being conducted in the area. The hammocks in which surveying occurred were L2/1, 4, 5, and 8, and L1/5, 6, 7, 9, 10a and b, 11, 13, 14, 15, and 16, as defined by Ruttenber and Weiner (1977). Trapping occurred between 8 May and 19 June 1985.

Sites were searched for areas most likely to contain woodrats or cotton mice. Areas with holes or stick piles were frequently chosen for trap-lines. Traps were set in areas with and without cover, around obvious holes, rock piles, or stick nests, under or on fallen trees, or by upturned or exposed tree roots. Special efforts were made to trap in areas not considered to be occupied by Key Largo woodrats or cotton mice (Schwartz, 1952; Hersh, 1978; Humphrey and Barbour, 1979): immature hammock, burned areas, and hammocks to the south of their presently suspected range. As indicators of woodrat presence were revealed by the trapping survey, additional sites were examined by walking surveys (no trapping) to gain information on

extent of the range and habitat use of the species.

Trap-lines generally were set at a site until both species of endangered rodents were captured there or capture of one or the other appeared unlikely. From 8 - 17 May, bait used was mixed birdseed. Rolled oats were used as bait for the duration of the study. During the time a line was set, most captured animals (including those of other species) were weighed (as an estimator of maturity) and their sex and apparent breeding condition noted before release. From 31 May on individuals were marked with numbers on the ventral side, using permanent black ink markers, in areas where prolonged trapping occurred. Recaptures, distinguished by numbers or natural marks (coloration, scars, etc.), were noted as they occurred.

Radiotelemetry and Dust Capsule Tracking

A new technique for studying habitat use and home range was designed and its feasibility tested on woodrats during the first phase of field work. The technique involved the use of fluorescent dust. Lemen and Freeman (1985) reported that, by shaking mice gently in a bag of fluorescent dust before release, their movements could be followed for some distance while the dust brushed off their fur onto surrounding vegetation. To achieve longer term tracking for this study, hollow dental acrylic capsules were manufactured (weighing 2 - 5 g), contoured to fit on the curve of the rump of the animal. The capsules were

filled with Radient Color Fluorescent dust of one of 3 colors (green, yellow, or orange) through a hole at the bottom of the capsule. The captured animals were anesthetized using methoxyflurane. They were collared with a Wildlife Materials (WMI) transmitter (150 - 151 MHz) weighing about 7 g. The capsule was then glued to the rump of the animal with the capsule's hole pointing downward to allow the dust to fall out. The hole, of sufficient diameter to let the dust through in a thin stream, was blocked by the weight of a 5 mm stainless steel ball bearing while the animal was stationary. Movement by the animal, after recovery from anesthesia and subsequent release, caused metal ball to be displaced and a trail of dust to be delivered behind it. An advantage of the dust capsule was that no close surrounding vegetation was required for a trail to be deposited. Movements could be followed in open or sparsely vegetated areas. Animals were released just after sunset at the start of their nightly active period.

Radiotelemetry was used for location of the animal in its daytime retreat, and for following rapid, large-scale movements. A WMI Merlin VI receiver and a collapsible hand-held yagi antenna were used to determine the direction of the radio signal. The animal's position was monitored remotely during its active period by triangulation from two positions outside the hammock. During the day the animal's retreat was determined by telemetry and directly approached. The retreat was then surrounded with traps to recapture the animal for refitting with a capsule containing a different color of dust, or removal of the

radiocollar.

The fine scale movements that occurred were revealed by following the trail of fluorescent dust left by a capsule-fitted animal during the nightly active period. An Eveready Fluorescent Land lantern equipped with a GE10047/F6T5BLB ultraviolet bulb caused the dust trail to fluoresce brightly. Generally, after release of a collared and capsuled animal, researchers would immediately leave the interior of the hammock so as not to disturb the animal's activity. With the use of the ultraviolet lamp, the trail of dust was followed before dawn the next morning, or on a following evening. Patterns of habitat use were noted. Flagging was tied at intervals along the route. By daylight, the locations of the flags were mapped with respect to fixed reference points. Animal positions determined by telemetry were flagged and mapped in the same way. On the maps, extreme points of movement, as revealed by dust tracking or telemetry, were connected using the "minimum home range" method (Mohr, 1947) to form the perimeter of the estimated home range.

General

Descriptions of vegetative qualities of the trap-line sites follow the terminology of Weiner (1977). Contact prints of aerial infrared photographs (22.5 by 22.5 cm) from the National Cartographic Information Center were used to distiguish areas of burned and unburned hammock. Areas were calculated using a GTCO

Digi-pad 5 digitizer, the GAP1 sofware program (GTCO Corp.), and an IBM/PC. Replicated Goodness of Fit Tests (G - Statistic) were used to evaluate possible trends in capture data.

RESULTS

Trapping Results and Site Characterization

Tables 1 through 3 contain a summary of capture data for all rodents taken in 45 trap-line sites from 8 May through 19 June. The number of trap-nights (traps set each night) are shown for each locality in Tables 4 through 7. Table 8 is a summary of total number of captures, trap-nights, and the trap-night success (number of captures divided by number of trap-nights) for Key Largo woodrats and cotton mice in each of the 45 sites. The sites are mapped in Figures 1 and 2.

Capture of juveniles and lactating females of both species indicated that the animals were actively breeding (Figures 3 and 4). Neotoma floridana and Peromyscus gossypinus may breed throughout the year in southern regions (Hersh 1978; Hamilton and Whitaker, 1979). Hersh's (1978) work suggested that woodrat breeding may peak in the summer months. Replicated Goodness of Fit Tests showed that the proportion of juveniles trapped in most five-day periods during May and June 1985 did not vary significantly from the mean frequencies (0.26 for woodrats, 0.11 for cotton mice). Deviation in proportion of juvenile woodrats was greatest in the second (May 15 - 19) and seventh (June 9 - 13) periods. In the second period, there appeared to be a decrease in the proportion trapped ($X^2 = 3.65$, d.f. = 1, $P < 0.06$); the decrease was significant in the seventh period ($X^2 = 3.85$, d.f. = 1, $P < 0.05$). For cotton mice the

Figure 1. - Twenty-six of the trap-line sites on North Key Largo.

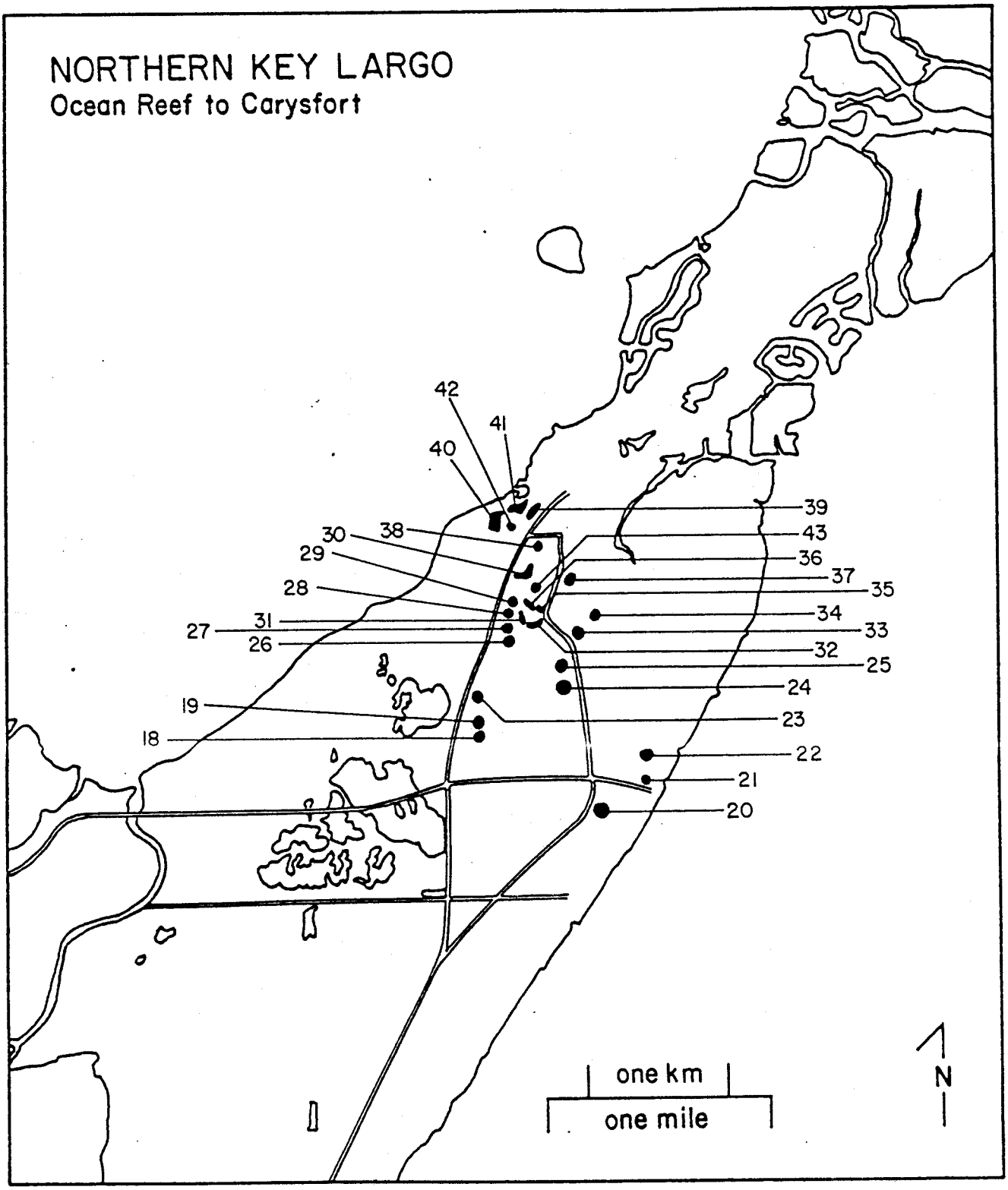
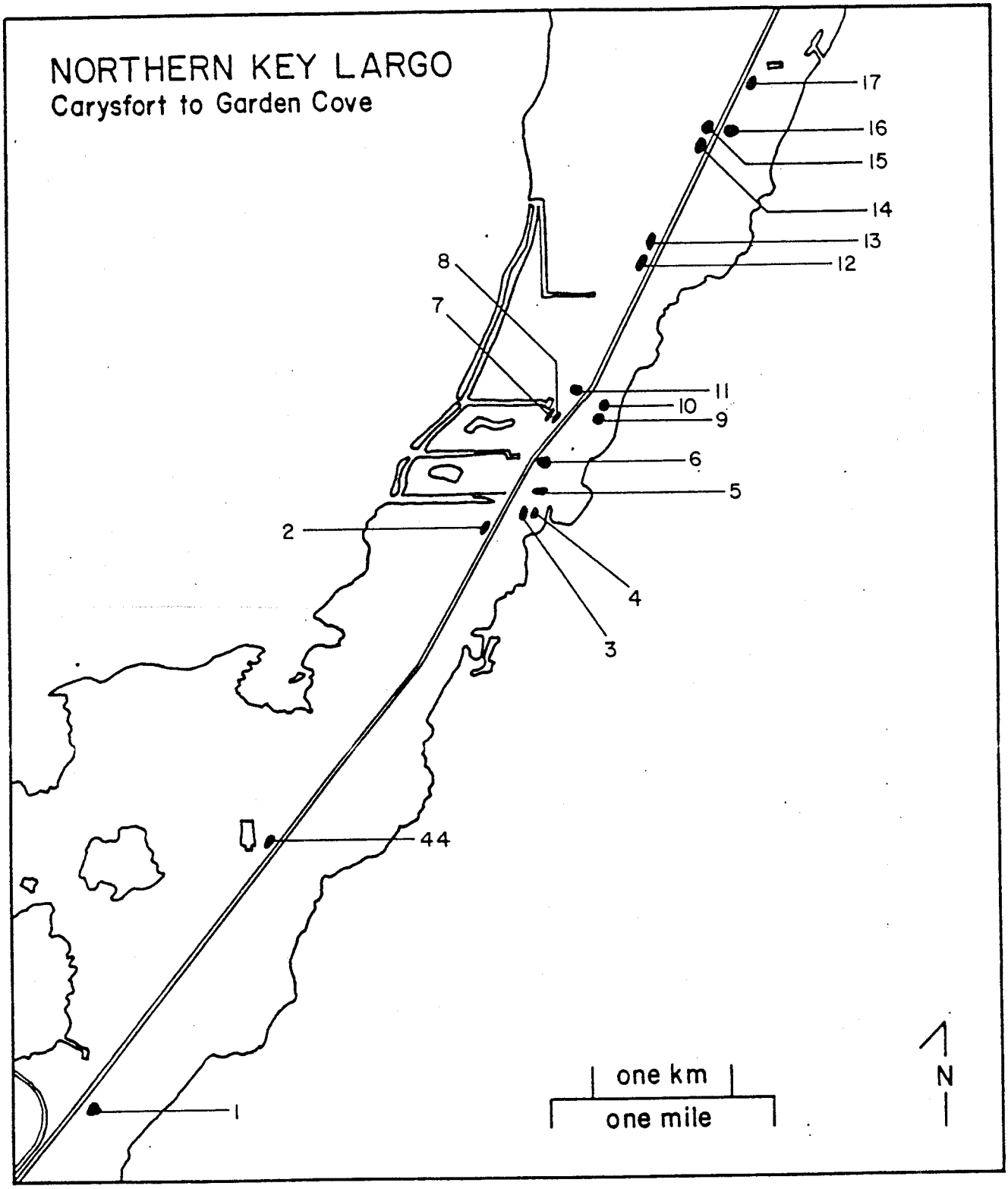

NORTHERN KEY LARGO
Ocean Reef to Carysfort
42
41
40
39
30
38
43
29
36
37
28
35
34
31
27
33
26
32
25
24
19
23
18
22
21
20
one km
one mile
N

Figure 2. - Eighteen of the trap-line sites on North Key Largo.


NORTHERN KEY LARGO
Carysfort to Garden Cove
17
16
15
14
13
12
8
7
11
10
9
6
5
2
4
3
44
1
one km
one mile
N

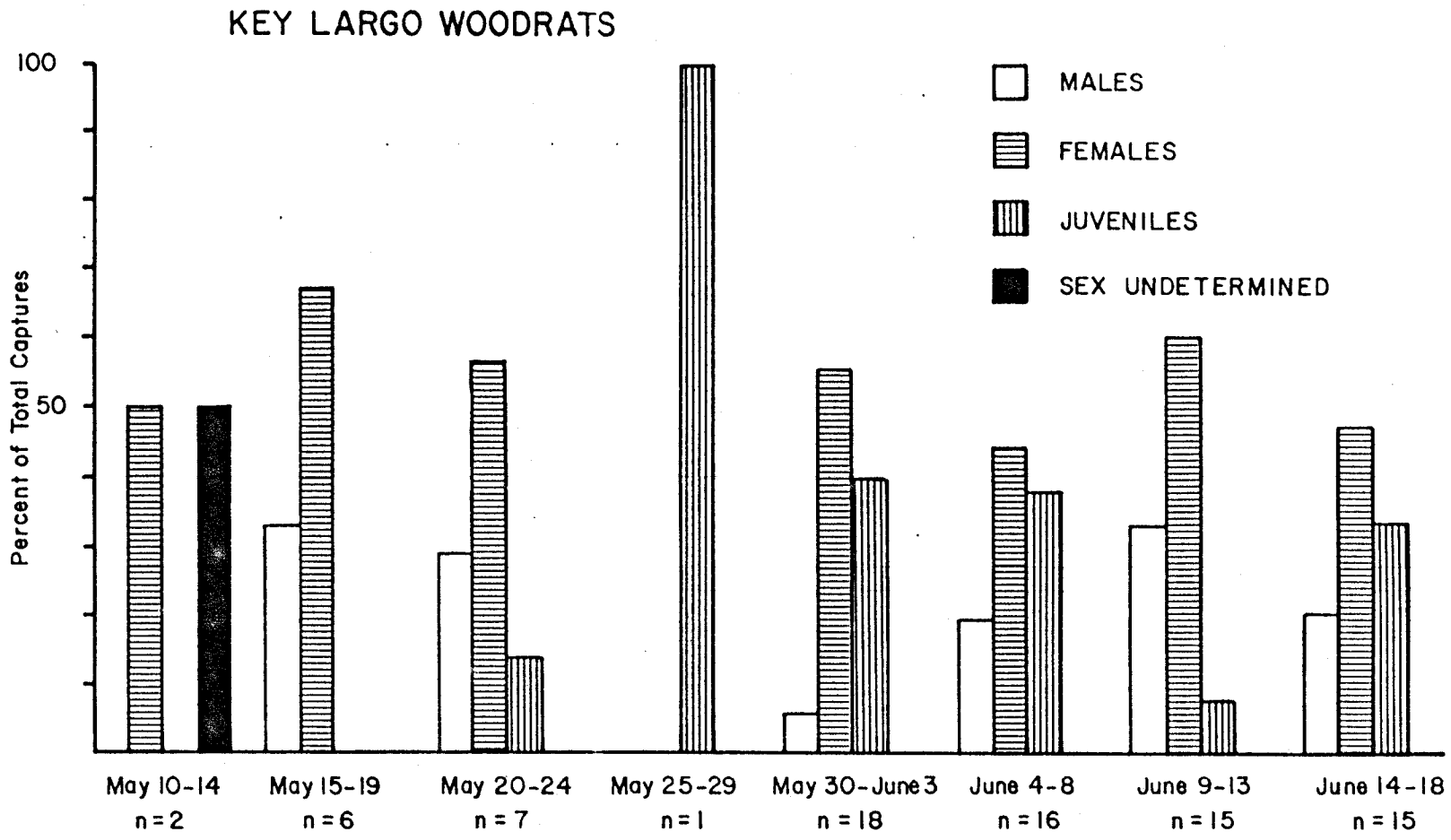
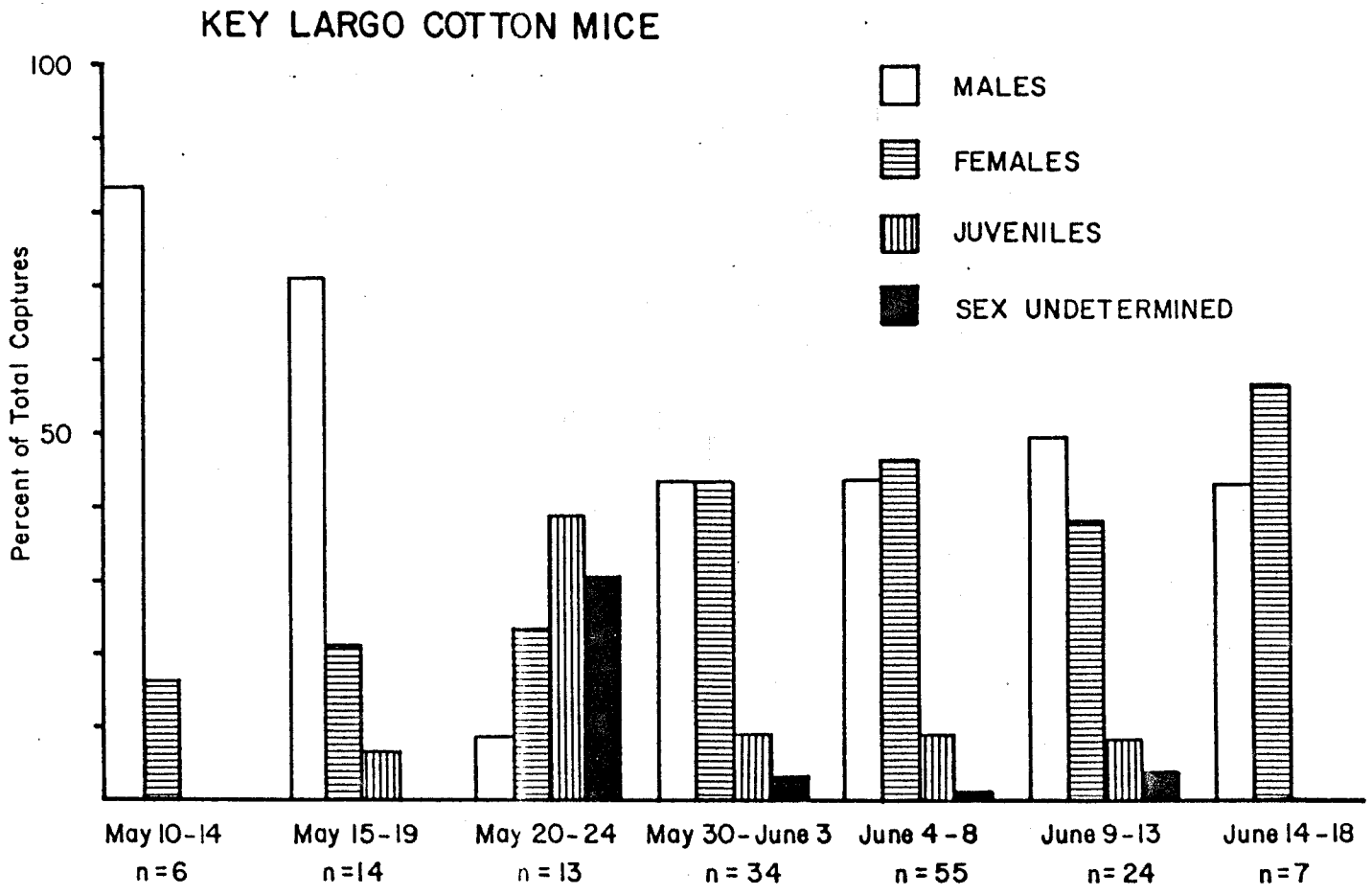

KEY LARGO WOODRATS
100
50
Percent of Total Captures
MALES
FEMALES
JUVENILES
SEX UNDETERMINED
May 10-14
n=2
May 15-19
n=6
May 20-24
n=7
May 25-29
n=1
May 30-June 3
n=18
June 4-8
n=16
June 9-13
n=15
June 14-18
n=15

Figure 3. - Relative proportions of adult and juvenile woodrats collected in eight five-day periods during May and June 1985.

Figure 4. - Relative proportions of adult and juvenile cotton mice collected in seven five-day periods during May and June 1985.


KEY LARGO COTTON MICE
100
50
Percent of Total Captures
MALES
FEMALES
JUVENILES
SEX UNDETERMINED
May 10-14
n=6
May 15-19
n=14
May 20-24
n=13
May 30-June 3
n=34
June 4-8
n=55
June 9-13
n=24
June 14-18
n=7

proportion of juveniles trapped did not vary significantly from the mean frequency in any period (X^2 = 10.42, d.f. = 6, P < 0.11).

The following section contains a site-by-site description of the trap-line sites. Although most of the 14 hammocks on which trapping occurred were extensively surveyed by Karen Achor (Weiner, 1979), the entries reflect the general traits of each hammock. On a finer scale, there is some variation from the general hammock descriptions. Therefore, I will briefly describe the qualities of each specific site on which trapping occurred.

Number of captures per trap varied depending on trap placement. Individual traps set in areas with certain characteristics would have better capture success. As the field work progressed it became apparent that these characteristics often indicated presence of one or the other of the two endangered species. Woodrats may be present in areas with no obvious stick nests. Indicators of presence may be limited to a three or four twig lattice placed over a hole, or holes in tree roots or rocks. Small round (ca. 30 cm diameter) clearings at the bases of trees or on the forest floor, where leaves and debris have been removed, are often associated with the presence of woodrats or cotton mice. Frequently seed husks are found on these cleared areas. These will be referred to as feeding stations in the following text. I am not sure which species (if

either) is responsible for creating the clearings; both were trapped there.

From capture data it appears that cotton mice live in their own holes, about 3 - 9 cm in diameter. Typically the holes are small (3 - 5 cm), and normally have leaves or pieces of bark pulled up to partially cover the entrance. The holes are usually located at the bases of trees, but may be found in areas with no closely associated vegetation in the middle of the forest floor. Cotton mice also are frequently captured near, or in, woodrat holes, nests, or runways. They also inhabit the recently burned areas vegetated predominantly by dense stands of Pteridium in the understory. It was not determined whether they occupied holes in these localities.

Site 1: (L2/5)

Site 1 was located in medium-high, medium-dense, canopied hammock. Understory vegetation was sparse. The site was contained within an area having "the oldest and most intact hammock vegetation" in the Garden Cove area (Weiner, 1979). Traps were set at one stick nest seen in the interior of the hammock, at the roots of two wind-throws (trees that have been tipped or toppled by high winds), and by holes both large (10 - 20 cm diameter) and small (3 - 9 cm diameter). An old, rotten pile of cut wood was found by an grassy road penetrating into the hammock. Several fresh sticks tucked into the spaces between logs

and some cleared ground around the wood pile indicated presence of woodrats. The only capture in 10 trap-nights, a female woodrat, was at this woodpile. No cotton mice were taken although the small holes indicated that they were probably present.

Site 2: (L2/1)

This was a dense, medium canopied hammock with a tangled understory of vines in many areas. A large strangler fig (Ficus aureus) stood at the edge of S-905. Woodrats had piled sticks within the complex of the trunk; 2 m to the south there was a large stick nest. Another large stick nest was found about 30 m west. Traps were set at the above locations, and at several small holes in the forest floor. In 20 trap-nights, two juvenile woodrats, a male and female, were taken from the western stick nest, and two adult males from the fig tree stick pile. One hispid cotton rat (Sigmodon hispidus) was captured at an entrance of the roadside stick nest.

Site 3: (L1/14)

This area consisted of young, relatively open forest with a medium canopy. Understory vegetation was moderatly dense to the north but thinned rapidly to the south. Barbed wire stretched through the site suggesting past presence of a farm. Young gumbo limbos (Bursera simarubra) and poisonwood (Metopium toxiferum) dominated the canopy. Few wind-throws were present, but many of the trees had well excavated roots with both large

and small holes. Traps were set by holes under roots and at one feeding station on the forest floor. Captures in 10 trap-nights included one male woodrat and one female cotton mouse. The woodrat was captured at the feeding station.

Site 4: (L1/14)

This area lay to the west of Site 3. Qualities of the canopy were similar, but Site 4 had a dense understory of tangled vines in areas. The north border of this site was a barricaded dirt road cutting to the east at cement pole 180. Piles of debris (rocks and old barbeque grills, etc.) had been incorporated into at least two woodrat nests found along its borders. Woodrats here attemped to annex one of our traps; sticks were piled on the trap and it was integrated into the nest superstructure overnight. Four stick nests were present in the area encompassed by the site. Traps were set in the debris by the road edge, and deeper into the hammock at one immense stick nest (ca. 1.5 m tall) at the edge of a solution hole, another stick nest further south, and by several small holes on the forest floor. In 40 trap-nights, one female woodrat was captured at the nest bordering the solution hole.

Site 5: (L1/14)

This site lay north of site 4 on the opposite side of the barricaded road at cement pole 180. The hammock at Site 5

had an open, medium canopy. The understory was thick with vines and trunks of smaller canopy trees. Traps were set at a large nest found at the edge of the unpaved road, and further north inside the hammock at one wind-throw, at several small holes, and at a feeding station at the bottom of a solution hole. In 20 trap-nights, one lactating female woodrat and three cotton mice (one male and two females) were captured. The woodrat was taken at the feeding station.

Site 6: (L1/14)

This site, running to the east and west of cement pole 175, had medium-dense, medium canopied hammock. A ca. 10 m strip of hammock vegetation ran parallel to the road here, between the power poles and the pavement. Princewood (Exostema caribaeum) was more abundant in this locality than at any of the other sites; it densely bordered the hammock and the edges of the isolated strip. Inside the strip there was a large stick nest and some exposed roots with large holes at which traps were set. In the hammock to the east, one other stick nest was seen on the trap-line site. In the interior of the hammock, traps were set at the bases of wind-throws or fallen logs. Captures did not occur on the strip, although traps were disturbed there. In 10 trap-nights, the one male woodrat taken was captured inside the hammock at the end of one of the fallen logs on the ground. One female cotton mouse was taken nearby.

Site 7: (L2/1)

The eastern border of this site had a medium-dense, medium canopy and relatively sparse understory vegetation extending about 50 m east of the trap-line. The trap-line itself, however, was set in medium-dense understory at the edge of the transition zone. A ridge of rocks had been piled at the hammock side of the transition. Some stick piling was evident around portions of the ca. 15 m long ridge. Traps were placed along this ridge and at the bases of several trees with small holes. In eight trap-nights, one juvenile male woodrat and one juvenile male cotton rat were taken at the rock-pile nest, and one male cotton mouse was taken at a hole beneath tree roots.

Site 8: (L2/1)

Hammock vegetation at the northern portions of this site was young, with an open canopy of medium height. The site lay roughly 100 m to the east of Site 7. Vines, Florida boxwood (Shaefferia fruitescens), and young canopy trees combined to make an almost impassible understory in some areas. Trapping was conducted at holes, small and large, under tree roots, a stick nest, and a feeding station. Further south in this site the hammock was more open, two large stick nests were found in a solution hole. Traps were also set by these nests. In 22 trap-nights, one female woodrat taken at a feeding station (and used in the dust capsule tracking study), and one male cotton rat taken in upturned tree roots, were trapped at the north end of

the line. A female cotton mouse was captured twice at the solution hole to the south.

Site 9: (L1/14)

Much of this site had open, low to medium canopy, and a medium-dense understory. Only one stick nest was found on the trap-line site, but this was a formidable nest, 2 m in diameter and about 1 m high. It was located in a tangle of vines and small saplings. Little other evidence of woodrats was present except for a few large holes at the base of trees. One juvenile male woodrat was taken at the nest, two male and one female cotton mouse were taken at holes beneath trees in a total of 20 trap-nights.

Site 10: (L1/14)

The hammock here had a dense, medium canopy and a relatively open understory. Ridges of rock, presumably plow furrows from earlier farming, were clearly visible. Achor noted in her survey of hammock L1/16 (Weiner, 1979), of which Site 10 is a part (as are sites 3, 4, 5, 6, and 9), that all the land had been previously cleared judging by the youth of the vegetation and that the rocks were lying in rows. Few wind-throws or many tree roots with holes were found here. Traps were set at three locations by holes at the bases of trees and at the one stick nest found on the site. In 20 trap-nights no woodrats were

collected, although some of the traps were disturbed. One female cotton mouse was taken at the base of tree roots.

Site 11: (L1/16)

The hammock here was young, the canopy low, and quite open. The understory consisted of thin saplings quite closely spaced. A large complex woodrat nest was located on the north edge of a barricaded road extending to the west opposite cement pole 171. This nest was incorporated into a large rock and refuse pile. Although it was clearly active, judging by the well worn entryways, no woodrats were captured there. In 10 trap-nights, one large female woodrat was taken at the end of a fallen log. One apparently pregnant cotton mouse was also captured on the forest floor along with one juvenile male black rat. It should be noted that this area is less than a mile from the Key Largo Landfill.

Site 12: (L1/15)

This site lay just south and west of the entrance to the Key Largo Landfill. The hammock was medium-dense, medium canopied. The understory was medium-dense, clogged somewhat by closely spaced saplings of canopy trees. No stick nests occurred on the trap-line site, but a large rock pile was found about 30 m inside the hammock which had several small sticks characteristically placed in a triangular framework above a hole in the rock pile. This hole did not appear to be an entryway;

however other apparent entrances to the pile were found within a half-meter of the sticks. In 20 trap-nights, one male woodrat was taken at the rock pile, and one cotton mouse taken nearby.

Site 13: (L1/15)

This site, located to the north of the entrance to the Key Largo Landfill, had a medium-dense canopy of medium height. There were few wind-throws or holes. Surrounding the site, at the boarder of the dump there were low piles of rock and cut vegetation. There was a ridge of rock that extended north to south along S-905 with some large and small holes. Traps were set along fallen logs, at the base of two upturned trees, at two large holes in the forest floor, and at the ridge of rock beside the road. In 85 trap-nights three woodrats were taken, all female, by fallen logs on the forest floor. Two black rats were captured, one was male. The male was trapped from an isolated large hole in the forest floor; the other was captured by a log in a trap that subsequently captured a woodrat.

Special care was taken to note direction of flight in these woodrats upon their release. None of them fled to nearby holes. Two bounded out of sight in the distant understory, and the third climbed a 10 cm diameter vertical sapling upon release. She remained teetering in the breeze at the top of the sparsely leaved Jamaica dogwood (Piscidia piscipula) while remaining traps were checked, showing no intention of descending. No cotton mice

were taken.

Site 14: (L1/15)

This site was contained in medium-dense, medium canopied hammock. It was located on the edge of a bulldozed road on the bayside, opposite the recently cleared (1984) Maxwell property. There was a large, old nest with well worn, large entryways at the base of a large tree. No recent additions of sticks had been made, and the entire surface of the nest was bare earth. In 20 trap-nights, traps set surrounding this mound collected only cotton mice: one male at a feeding station on a tree base, and a male and female at the large earth nest. However, traps were baited with birdseed (instead of the rolled oats used later) which seemed, from capture data, less enticing to woodrats than oats.

Site 15: (L1/15)

This site had a medium-dense, medium canopy. Poisonwood and pigeon plum (Cocoloba diversifolia) seemed predominant. One highly mounded stick nest was found, isolated from any supporting tree, in the interior of the hammock. A feeding station was nearby. Traps were set at both of these locations, but the center of woodrat activity appeared to be in a ridge of rock at the edge of S-905. A key rat snake, Elaphe obseleta deckerti, was found dead and mangled by the entrance of

one of the holes in the ridge. On 23 May 1984 one of these snakes was captured entering a presumed woodrat hole just south of the road to Dynamite Dock, North Key Largo. They undoubtedly prey on woodrats. The snake at site 15 could have been killed there by a larger predator (a raccoon or opossum) or hit on the road and carried to the site by turkey vultures. In 20 trap-nights, no woodrats were taken at the interior stick nest, but traps were disturbed at the feeding station. At the rock ridge, three woodrats were captured: two females (one juvenile) and one juvenile male. A female cotton mouse was taken nearby.

Site 16: (L1/13)

In this site the canopy was moderatly dense, and medium-high. The understory was sparce in the interior of the hammock. Woodrat nests were immediately apparent upon entry into the hammock; two large stick nests were situated less than 2 m from each other, and rocky ridges created by the power pole right-of-way seemed to have been colonized as well. Beneath the trees there were many large holes. Traps were set throughout this area. In 20 trap-nights, one female woodrat was captured at one of the stick nests. Two male cotton mice were captured from holes by fallen logs nearby. Achor noted some rock piles within the hammock "indicating a much earlier clearing" (Weiner, 1979). The hammock had matured greatly since the clearing at the trap-line site, and thick spongy layers of humus carpeted the ground. This thick layer may facilitate the digging of holes, and explain the high hole density.

Site 17: (L1/13)

Two-thirds of the hammock containing Site 17 appears to have experienced a relatively recent burn. Achor noted (Weiner, 1979) that fire in the northern portion of the hammock was "suggested by presence of bracken fern and younger individuals of hammock vegetation". Although the forest was young, woodrats were present on the site. Three stick nests were found. Two lay to the east, and one to the west, of the power pole right-of-way (between cement poles 131 and 132). The eastern "stick nests" were constructed largely of bark, instead of the usual small twigs. One of the bark nests was at least a meter in height. The interior of the hammock was densely vegetated by saplings, tangled vines and bracken. In the trap-line site there was a low open canopy 5 - 6 m in height. In 10 trap-nights one female woodrat was taken from the stick nest between S-905 and the power poles, and one female cotton mouse from a stick nest to the east of the poles.

Site 18: (L1/9)

This site had a dense, medium-high canopy. The understory was open. No stick nests were found but numerous large holes were present under tree roots and by large fallen trees. In 10 trap-nights one male woodrat and one male cotton mouse were taken, both by holes under tree roots.

Site 19: (L1/9)

This site lay just to the north of Site 18, and the qualities of the two sites were similar. Weiner and Achor (Weiner, 1979) noted the "hilly" topography in this hammock. Large (12 - 15 m) trees topped these "hummocks". The hummocks themselves were riddled with large holes occupied by woodrats and smaller ones at which cotton mice were captured. No stick nests were located on the trapping site, capture of woodrats in traps placed by the mounds indicated that the animals inhabit the tree root mounds without adding sticks to the structure. This behavior was also noted in Sites 20, 22 - 24, 26, 29, 30, 33, Traps were placed by small holes in at the bases of wild tamarind trees as well as by the tree root mounds. Sixty-two trap-nights yielded seven woodrat captures: five females (three juvenile) and two males (one juvenile). These animals were all taken from one mound. Four cotton mice were captured at the bases of wild tamarinds: three males (two juvenile) and one female.

Site 20: (L1/11)

This site had a medium to medium-high, dense canopy. Evidence of woodrats was everywhere, there were six stick nests on the site as well as many large tree root holes that were apparently as frequently used by the woodrats. Two of the six stick nests had many more sticks added to them than the other four which were more embellished holes than free standing nests.

Woody vines (Dalbergia) stretched into the canopy from the forest floor. Many cut logs or limbs lay on the ground; several wind-throws were tipped or fallen. Traps were set only around woodrat holes or stick nests. Birdseed was used as bait from 13 - 17 May during which time no woodrats were captured. Two days after traps were rebaited with rolled oats, woodrats began entering them. Similar results were obtained at Site 38. In 148 trap-nights at Site 20, there were 15 captures of woodrats: 7 different females, one (used for radiotelemetry/dust capsule tracking) captured four times, one adult male, recaptured three times, and one juvenile male. Three of the females were, or had recently been, lactating, and one appeared to be old with a stumped tail. Three different female cotton mice were taken; one lactating female was captured twice. Another female weighing only 16 g was lactating, and one male was parasitized by a bot fly larva.

Site 21: (L1/10b)

This site was located in relatively open, medium canopied hammock. The understory was dense with woody stems of vines and dead understory vegetation. The area was close to the transition, located 50 m to the east. Traps were set at a large stick nest that was built around a 0.5 m DBH wind-throw. All traps placed here were disturbed the following morning, presumably by raccoons. There were no captures at this site in nine trap-nights.

Site 22: (L1/10b)

This area contained some of the highest canopied hammock of all sites in which trapping occurred. The understory was open and the hammock floor had the hilly topography of Site 19. Many large canopy trees perched on hummocks in which woodrat holes were apparent. Smaller holes were also abundant at the bases of smaller diameter trees. Traps were set only by holes, both large and small. No stick nests occurred within the site. Captures in 60 trap-nights included two woodrats and three female cotton mice (one juvenile). The juvenile still had grey pelage. One of the larger animals was lactating. Cotton rats were captured on both nights at the same location as the male woodrat; a hole-riddled root mound 10 m east of a sunny, grassy road cut.

Site 23: (L1/9)

This site was located in medium-dense high canopied hammock. The understory was largely open. Many wind-throws and fallen or cut logs lay on the forest floor. Other wind-throws, slightly tipped, had extensive excavation beneath them, presumably by woodrats. A pile of woodrat scats was found at the edge of the road at its junction with the survey cut between this site and the State land just south. Only a low understory was present at the site of the scat pile; the area had been cleared. Traps were set at the bases of trees at small and large holes.

No stick nests were present on the trap-line site. In 10 trap-nights, one juvenile female woodrat and two female cotton mice were captured.

Site 24: (L1/10a)

This site was located in medium-dense to open, medium canopied hammock. Achor noted in her survey of the general area (Weiner, 1979) that "Judging by the variations in species, densities and canopy heights, sections of the forest had been disturbed in various ways at different times". Portions of the trap-line were set in relatively open canopied hammock with an open understory. Char on old stumps indicated that this open area may have burned with other portions of the hammock in 1977, but limited vegetation suggested that it could have been cleared or thinned more recently. In other portions of the site the canopy was less open, and larger trees and some wind-throws were present. Traps were set by large holes at the bases of young (10 cm DBH) pigeon plums in the open areas, and at the bases of two large (40 - 60 cm DBH) wild tamarind (Lysiloma bahamense) wind-throws. One of the wind-throws had a large stick nest integrated into its roots. One other small, free-standing stick nest was found on the trap-line site. Three woodrats were captured: a male (captured twice) in the relatively open area, and two females (one captured twice), each at the base of a wind-throw. Three female cotton mice (one captured twice), and four males (one captured four times), were taken at wind-throws and at tree

root holes. Two of the mice were parasitized by bot fly larvae.

Site 25: (L1/10a)

A dirt road to the "Gumbo Limbo Gun Range" separated this trap-line site from Site 24. There was a medium-dense, medium canopy, and medium-dense understory vegetation. All traps were placed around a large (ca. 60 cm DBH), upright wild tamarind tree and a close by wind-throw. A stick nest complex with at least six entrances was built at the base of the upright tree. Three female woodrats were repeatedly caught at the nest: one adult (captured four times), and two juveniles (one captured five times, the other three times).

Site 26: (L1/6)

Located in medium-high canopied hammock, this site had many of the "hummocks" or tree root mounds that seem to be associated with older, more mature hammocks. The mounds here were higher than those in site 19 and equally riddled with holes. No stick nests were found on the site. Traps were set at several of these mounds at large holes. Ten trap-nights resulted in the capture of one juvenile female woodrat, from a large hole in a mound, and three cotton mice (two males and a female) from holes between the roots of trees.

Site 27: (L1/6)

This site lay to the north of Site 26, and was similar in overall qualities, but evidence of logging was very apparent here. Cut stumps of mahoganies (Swietenia mahogani) were everywhere. At the bases of these stumps there were numerous small holes (and quite a few larger ones) at which most of the traps in the line were set. Several were set by holes betweem the roots of smaller living trees (e.g. pigeon plum) as well. Only cotton mice were taken here in a surprisingly large number of trap-nights (40). The mice however were easily captured. Eight individual cotton mice were taken: four adult females (three captured three times each), one juvenile female, two adult males (one captured four times, one captured twice), and one juvenile male. Individual mice were recaptured as much as 15 m from their previous capture site.

Site 28: (L1/6)

Site 28 lay to the north of Site 27 across a dirt road. The hammock at the site was quite dense, medium-high canopied. The understory was open. Several large wind-throws had fallen on the hammock floor, and others were tipped with large portions of roots exposed. Small and large holes were seen entering into the remaining earth about the roots. No stick nests were found on the site. Traps were set at holes throughout the area. In 40 trap-nights, only cotton mice were collected: one female captured three times, two males (one juvenile) captured twice

each, and one that escaped before its sex could be determined.

Site 29: (L1/6)

The north side of this trap-line reached the southern border of an expansive burned area (ca. 15.8 ha - 39 acres) in hammock L1/6. The qualities of the canopy were similar to those at Site 28. Some cut stumps were present indicating past logging activities. Most of the larger trees had large, well-excavated root mounds with large and small holes. Traps were set inside some of the larger holes in the mounds, and beside other smaller holes at the bases of trees. No stick nests were seen on the site. In 30 trap-nights, animals captured included one female woodrat from a large hole in a tree root mound, and seven cotton mice (one was a recapture of a 24 g female trapped previously more than 30 m away in Site 27). The woodrat had a large, healed, but naked scar on her mid-dorsum.

Site 30: (L1/6)

The trap-line was set in medium canopied hammock. Both birdseed and rolled oats were used for bait. The canopy varied from open to dense canopied, immediately surrounding the trap-line site, due to a burn that occured in the hammock in the spring of 1975 (Weiner, 1979). When traps were first set in the site on 13 May, no fresh stick nests were found in the unburned western third of the top section of hammock L1/6 (as delineated by the

new road joining old 905 and S-905 and the first dirt road to the south). Due to the thickness of the understory vegetation, the burned area in the western third of the first section was searched less throughly, but on several transects no nests or holes, large or small, were found. One wind-throw had some sticks associated with it, but there appeared to have been no additions to the pile in some time; it was not recognizable as a stick nest. After a rainstorm on 16 May, new sticks began accumulating on the pile.

Traps were set at large and small holes at the bases of trees, a feeding station, the stick pile, and at a large, slightly tipped wind-throw. In 40 trap-nites in this locality, we captured one female woodrat four times in three areas: once at a feeding station (this was the only successful woodrat capture using birdseed as bait), once at the pile of sticks, and twice at the slightly tipped wind-throw. This animal was used in the radiotelemetry/dust capsule tracking study.

Site 31: (L1/6)

This site was located on an area that was burned in 1975 (Weiner, 1979). It was no longer forested except for scattered wild tamarind and Jamaica dogwood trees (4 - 6 m tall). Bracken fern was predominant in the understory and grew thickly - to a height of almost 2 m further west, in the center of the burned area. Small poisonwood and mahogany trees were also found colonizing the area. Potato tree (Solanum erianthicum) was

common on the edges of the burn, especially near the road and along the hammock/burn ecotone. Traps were set on the burn side of this ecotone in runways found in the mats of dead bracken plants and around the bases of living plants. Cotton mice were captured here, as were cotton rats. In 20 trap-nights, a male and female cotton mouse (each recaptured once) and three cotton rats were trapped. Since the runways found were large, they likely belonged to the cotton rats, although they appeared to be used by the mice as well. No woodrats were captured in this locality.

Site 32: (L1/6)

Site 32 lay along the hammock/burn ecotone immediately to the east of Site 31. There was a rocky ridge that had been plowed up at the hammock's edge. Otherwise, the site was similar to Site 31. Traps were set in the bracken, along the rocky ridge, and at the bases of some trees at the edge of the hammock. Cotton mice were found throughout the area: five were captured in 81 trap-nights, two females and three males. One female cotton rat was taken, and no woodrats.

Site 33: (L1/10b)

Although the site was isolated from other forested areas by Dispatch Creek Slough, old 905, and a golf course, the area still had copious signs of woodrats. The hammock had medium-high, medium-dense canopy. The understory was open. Tree

root mounds were large and contained numerous large holes. A black racer (Coluber constrictor) was seen entering one of these holes on 6 June. In 10 trap-nights a female woodrat and female cotton mouse were taken from holes under tree roots. No stick nests were seen on the trap-line site.

Site 34: (L1/10b)

Still more isolated from other hammock than Site 33, site 34 was bounded by dispatch creek, parking area and buildings on the Ocean Reef Club, and a golf driving range. In this portion of hammock, two stick nests were found on the trap-line site, and numerous holes under tree roots. Traps were set beneath and around a large wind-throw that had become the nucleus of a stick nest, and at both large and small holes at the bases of trees. Although traps were disturbed nightly (probably by raccoons) eventually - in 39 trap-nights - a woodrat (female) and two cotton mice (a male and female) were captured. The cotton mice were taken in small holes at the bases of 10 cm DBH trees.

Site 35: (L1/6)

The traps were set in an east-west line, punching out towards the center of the burned area in hammock L1/6. No forested hammock abutted the trap-line, bracken and the scattered wild tamarinds described above (Site 31) were the predominant plant species. The bracken grew to a height of 1.5 m here with a thick (20 cm) layer of dead fronds creating a raised thatch over

the ground. Traps were set under the cover of this, and other, dead vegegation. Five cotton mice were captured here: two females, two males, and one whose sex was not determined. No woodrats were taken.

Site 36: (L1/6)

This trap-line strung out to the west of the line at Site 35 into the center of the burned area. The area was similar to sites 31, 32, and 35, except that the bracken was thicker and taller (up to 2 m). Traps were set below the layer of dead bracken thatch at the bases of the ferns. Both cotton mice and cotton rats were taken here. In 20 trap-nights, two female cotton mice (one captured twice) and one male (captured twice), three female cotton rats (two male, and one whose sex was not determined) were trapped. There were no signs of woodrats in the area.

Site 37: (L1/7)

The site was in quite open, low to medium canopied hammock. The understory was thick with saplings of canopy trees. On the west the trap-line was bordered by old 905; on the east by buttonwood transition. Holes (large and small) were found at the bases of trees and of several wind-throws. No stick nests were found on the trap-line site. Traps were set by holes. In 10 trap-nights one male woodrat and three female cotton mice (on

juvenile) were captured.

Site 38: (L1/6)

This area had quite dense, medium canopied hammock. The understory was also quite dense. Traps were set at the one stick nest found on the site (another was later discovered ca. 20 m west), in a solution hole in which there were approximately six 5 cm diameter holes with bare earth around them, and at a small hole in the roots of a tree. Three woodrats were taken at the stick nest in 70 trap-nights: two males and a female. Initially traps were baited with birdseed; woodrat captures occurred after traps were rebaited with rolled oats. One cotton mouse was captured in the solution hole. Upon release the mouse entered a hole that was found to be typical for the species; leaves and bark partially covered the entrance. The open holes in the solution hole with leaves and debris cleared from the entrances apparently belonged to land crabs which were trapped there as well. The other cotton mice were taken at the large hole at the base of a tree (these all may have been captures of the same individual).

Site 39: (L1/5)

The site was in quite open, medium canopied hammock. The understory was clogged with mahogany and poisonwood saplings. The area directly to the south was recovering from a severe burn and it appeared that the fire entered the trap-line site as well.

The hammock was young compared to stands to the north and west. Few holes were seen in the area, large or small, and no stick nests were seen. Traps were set at the base of two wind-throws, by a pile of bark that lay at the base of a tree, and by a small hole found by the roots of a gumbo limbo. Only cotton mice were taken here: three males and one female, who was captured twice. Captures occurred at the small hole, one of the wind-throws, and by the bark pile.

Site 40: (L1/5)

This site lay to the south of the burned area in hammock L1/5. The hammock canopy was medium-high and quite dense, mostly composed of wild tamarind trees. The understory was largely open. The floor of the hammock was covered with branches of trees, many of which had been cut by loggers. At the bases of most of the tamarinds there were one or two small holes. The earth around the trees was brushed clean of leaves and debris. Some or all of these cleaned areas may have been feeding stations. All but one of the cotton mice taken here (one female and three juvenile males) were captured at these areas. The other mouse (a male) was captured in a rock pile beside a dirt road entering the area.

Site 41: (L1/5)

This site lay directly to the north and west of the

L1/5 burned area. It appeared to have a greater diversity of canopy tree species than either Sites 39 or 40. The hammock here was dense and medium canopied. The understory was clogged with saplings and vines at the eastern and southern edges of the trap-line site at the border of the burn. The western border of the site was marked by buttonwood transition. One large and one small stick nest were found on the trap-line site, both at tipped wind-throws; traps were set at each. Traps were also set at holes by tree bases and fallen logs, and by some in the buttonwood transition that proved, from captures, to be land crab holes. In 195 trap-nights here a woodrat never entered the traps until the last night, when a juvenile male was captured by a stick nest. Cotton mice were regularly taken: two separate females were trapped (one was captured twice), and there were seven captures of males (most of which probably represented recapture of one individual that was not marked).

Site 42: (L1/5)

The entire trap-line at this site was set at a wind-throw with holes below it at the southern edge of the burned area in hammock L1/5. No captures occurred here in 10 trap-nights.

Site 43: (L1/6)

This site was located at the northern edge of the L1/6 burned area. Vegetation at the site resembled Sites 31, 32, 35,

and 36 closely; bracken predominated. Traps (initially baited with birdseed, then with rolled oats) were set under the thick thatch of dead fern to the south of the east-west dirt road passing through the hammock. Although no woodrats were captured here in 70 trap-nights, three cotton mice (two males and one whose sex was undetermined), and 11 cotton rats (three females, four males, and four whose sex was not determined) were taken. All captures may not have been separate individuals; no animals were marked.

Site 44: (L2/4)

This site was in the eastern section of hammock L2/4 which Achor, in her survey of the area (Weiner, 1979), reported as being "the most diverse, most mature and least disturbed" portion of the hammock. The site was medium-dense, medium-high canopied. The understory was largely open in most places, but clogged with vines in others. Two stick nests, and numerous holes under tree roots, were found. Scats of a juvenile woodrat were seen at one of the nests. In 40 trap-nights, only a tail of a woodrat was collected, skinned off by the door of one of the traps; it was clearly identifiable. The trap had been placed next to a large hole beneath a tree root. A male cotton mouse was captured here beside a similar hole. Traps at this site were baited with birdseed.

Site 45: (L2/8)

This site lay to the east of US 1, 0.8 mi north of the Key Largo Elementary School. The hammock here had dense, medium-high canopy; the understory was relatively open. Large open holes occurred at the bases of many trees and wind-throws. Traps were set at these holes, and at a large pile of sticks probably put in the area by the owner of the property (not woodrats). Trapping was conducted from 8 through 10 May, during which time traps were baited with birdseed. Traps were set again in the area from 9 through 18 June baited with rolled oats. Although the area vegetatively and topographically resembled hammocks in which woodrats and cotton mice had been captured further north on Key Largo, neither species was collected there in 199 trap-nights.

Radiotelemetry and Dust Capsule Tracking

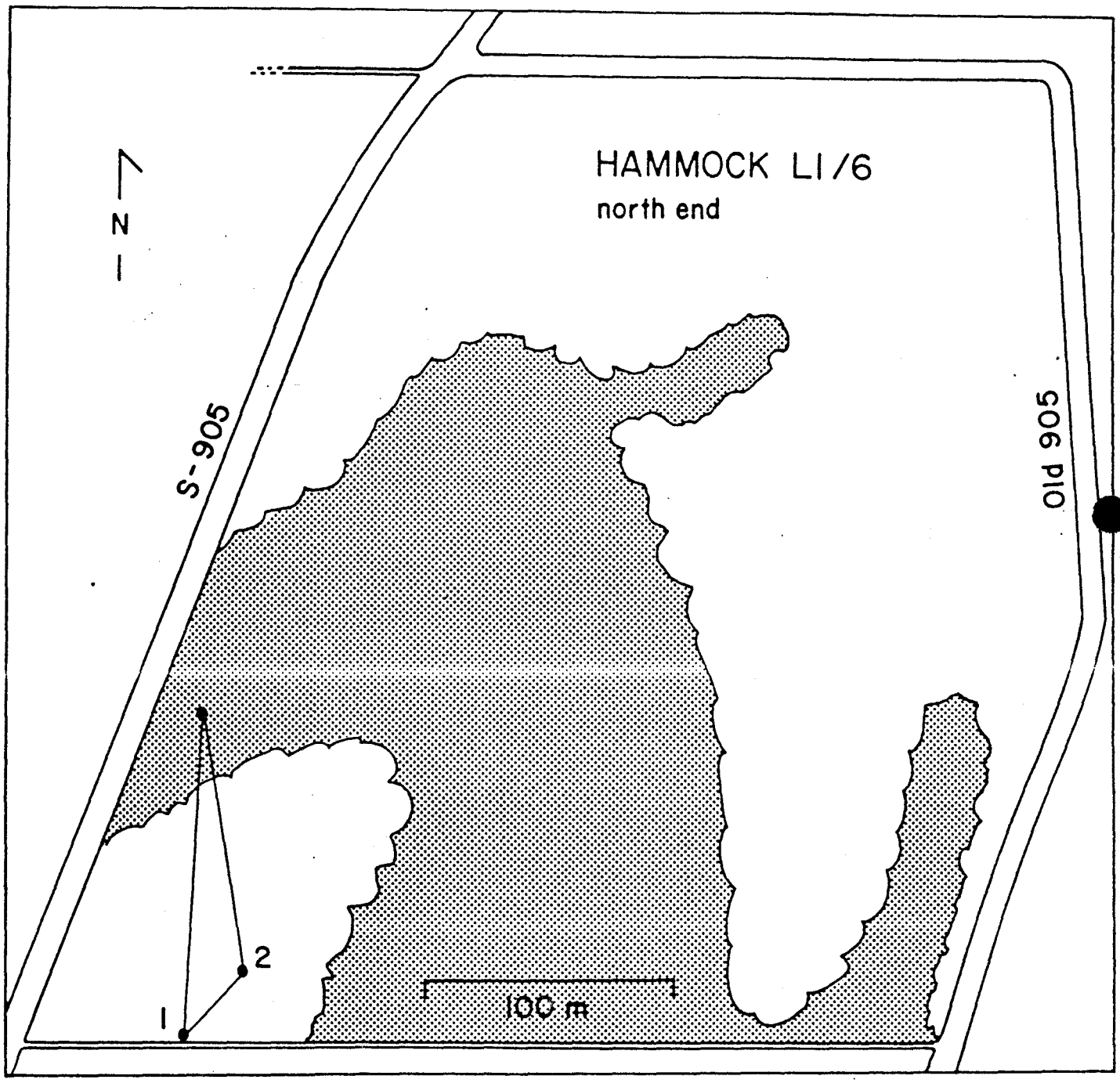
During the first field session, from May through June, prototypic capsules capable of leaving trails of fluorescent dust were affixed to the rumps of three female woodrats to assess the suitability of the method for determining home range and habitat use of the animals. A radiocollar was attached to the necks of two of the three woodrats to facilitate recapture after the charge of colored dust had been expended. After recapture, the capsule could be recharged with a different color of dust, or replaced with a new capsule containing a different color. Using three colors it was possible to track animals on three successive nights without confusing the pathways traveled.

Animal 1:

The first woodrat fitted with the radiocollar and dust capsule was captured at Site 30 on 14 May. She was released with the tracking devices on 15 May. The following morning, just before dawn, use of the ultraviolet light revealed that she had climbed a ca. 10 cm diameter strangler fig and crossed over in the canopy from this to other trees. The trail showed that the woodrat had repeatedly climed up and down the fig, and had entered into holes at bases of two separate trees. When on the hammock floor, she crossed a broad open area by traveling on a fallen log. The charge of dust seemed to be exausted before the end of the night as there was no trail returning to the daytime retreat. This retreat was found by telemetry in a tipped wind-throw (nest 1; Figure 5). There were no sticks or twigs around the entrance.

On 18 May the woodrat was recaptured and fitted with another dust capsule. Apparently she had removed the first capsule, a process which left no fur on her rump. A new capsule was manufactured. It was glued to the animal with epoxy about one hour prior to release. It was chewed off during this hour. The capsule was re-glued about five minutes before release. Between the time of release and the time the woodrat first moved she apparently chewed off the capsule again; no dust trail was found coming out of the daytime retreat. Between 2051 and 2245 she was followed using radiotelemetry. She moved 140 m north of

Figure 5. - Estimated home range of a female woodrat (Animal 1) from two nights of radiotelemetry/dust capsule tracking at Site 30. The home range (lower left) is shown in relation to topographic features of the surrounding area. It included an area of 1600 m^2. Nests occurring on the site are labeled 1 and 2. The shaded area between S-905 and Old 905 is hammock that burned in 1975, the rest is older forest.


HAMMOCK LI/6
north end
N
S-905
Old 905
1
2
100 m

the daytime retreat before turning back. She entered an area that was part of the land burned in 1975. This was the first time a woodrat had been recorded utilizing a burned area. At 0050 on 20 May she was recaptured at the newly constructed, or reconstructed, stick nest mentioned in the description of Site 30 above (nest 2; Figure 5).

From results of the dust capsule tracking and radiotelemetry, the animal occupied an estimated home range of 1600 m^2 (about 1.1 acres). The triangular shape of the home range and its relationship to roads and features of the hammock is shown in Figure 5. The dust tracking on 15/16 May indicated that the animal spent much of the night in the southern third of the triangle. The northern two thirds were added to the total area occupied when she ran north in the evening of 19 May.

When her daytime position was recorded on 16 - 18 May she was found only in nest 1 (Figure 5). She visited nest 2 on the night of 15/16 May and was captured there on 19/20 May. Because this female had apparently learned to remove the dust capsule, the radiocollar was taken off and she was permanantly released on 24 May.

Animal 2;

Epoxy was also used to fix the next dust capsule to a female woodrat captured on Site 20 on 19 May. A strand of cotton

batting was bonded into the surplus glue that oozed out at the edge of the capsule as it was pressed on the back of the woodrat. A foul tasting but hamless mixture of antibiotic and heartworm pills (pers. comm. Dr. Bush - Veterinarian, Ramrod Key) was soaked into the cotton fibers surrounding the capsule. A drop of the mixture was placed on the animal's tongue as it recovered from the anesthesia. This apparently had the desired effect of discouraging the animal from chewing at the dust capsule after release on 23 May. Although hard rain on 24 May prevented seeing whether the first night of tracking was complete (i.e. whether the dust led to her daytime retreat), an extensive trail was left by the animal. Again the animal spent most active time in the trees; clearly visible dust trails led up the woody Dalbergia vines to canopy 15 m high.

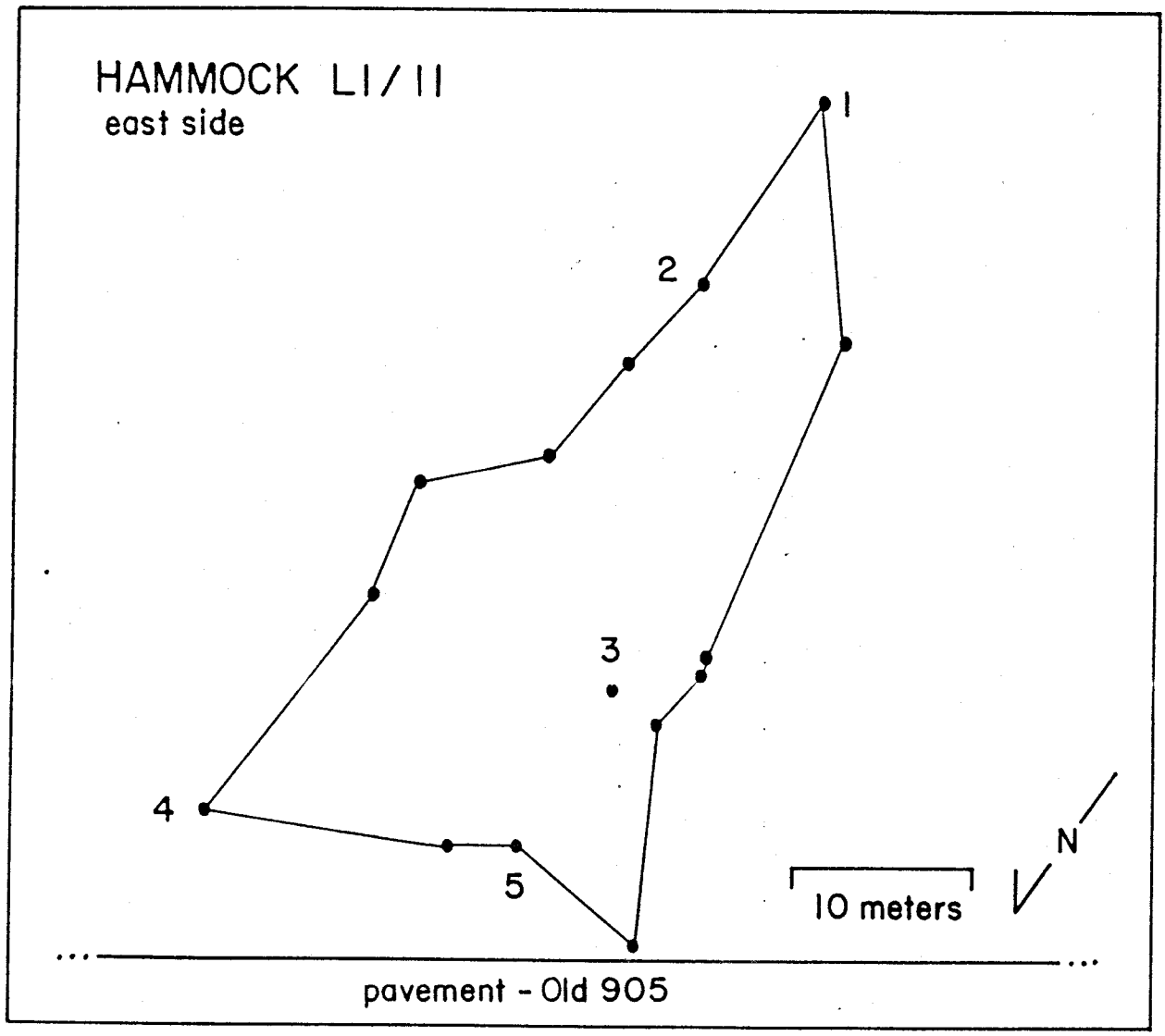
The animal was recaptured on 30 May and fitted with a new capsule (she had by this time removed the old one) attached in the same manner as the previous capsule. It was apparent, from following the trail before dawn on 1 June that the animal again spent much of the night in the trees, judging by the amount of dust that had fallen into the canopy of the understory, and had used most of the same holes, vines, and pathways for travel as used on the previous night of tracking. Two areas in which proportionatly more dust had fallen from the canopy were directly beneath blossoming Jamaica dogwood trees, indicating that the animal may have occupied these trees for longer periods of time.

Apparently the animal was still in the trees while the trail was being followed between 0450 - 0615 h. No return trail went to the daytime retreat at 0545 but there was one at 0615. The morning trail led down from the trees bordering old 905, thickened at a spot in front of the door to the daytime retreat (indicating that she paused there, probably grooming), then entered the nest. The dust charge had lasted for the entire night.

When the animal was recaptured on 3 June, contact cement was used to affix the capsule instead of epoxy in an attempt to achieve a more flexible bond. The distasteful liquid was used around the capsule as with the two previous trackings. The animal was released on the same day at 2130 (just after dark). On returning to follow the trail, it was found that the animal had left its nest, climbed into the canopy (at the site of one of the two blossoming Jamaica dogwoods), moved about some, then chewed off the capsule. It was lying on the forest floor where it had dropped from 15 m above. Even from this aborted tracking attempt, patterns of movement could be seen. Again in most areas, the fluorescing dust overlayed the dust of the previous nights. Trails from the three nights, crossing logs or open forest floor, did not often deviate from each other. When areas were traversed, they were traversed in the same way on subsequent nights of tracking.

The animal used three separate nests as daytime retreats. All three were at the bases of trees, accessed through

Figure 6. - Estimated home range of a female woodrat (Animal 2) from three nights of radiotelemetry/dust capsule tracking at site 20. Nests occurring on the site were numbered 1 - 5. The area included in the home range during these nights was 620 m^2.


HAMMOCK L1/11
east side
1
2
3
4
5
10 meters
N
pavement - Old 905

holes in the roots. All three nests had had some sticks added above and around the entrance holes. These nests are labeled 3, 4, and 5 in Figure 6. Nest 3 was used as a daytime retreat on 29 May, nest 4 on 8 - 11 June, nest 5 on 28 May, 1 - 3 and 5 - 7 June. The woodrat was initially captured on 20 May at nest 1, the largest stick nest on the trap-line site (Figure 6). On dates when daytime position was checked she was not found occupying this nest; however, her trail led in and out of the nest via two holes on 24 May, indicating that she had briefly entered it. On 31 May/1 June her trail passed over roots at entrances to nest 2 but did not enter the nest (Figure 6). Her behavior was interesting because when site 20 was visited in 1984 nest 2 appeared in good repair with fresh additions of sticks; in 1985 it had no signs of being maintained by woodrats. Perhaps it was not being used.

It is likely that other woodrats occupied the nests as well. Three different females were captured at nest 3, a male was captured three times at nest 4, and a juvenile male and female at nest 5. A map of the nests and holes used by Animal 2, and the estimated home range are shown in Figure 6. The animal occupied a combined area of 620 m^2 (0.15 acres) on the nights she was tracked.

Animal 3:

This female woodrat was captured at Site 8 on 12 June.

She was released carrying a dust capsule on 18 June. She was not radiocollared because it would have been necessary to retrieve the collar before field work ended on 21 June and recapture did not always immediately occur. The animal was released in an open area (the capture site) instead of a hole or nest. From this exposed area she may have rapidly run some distance away in dense understory vegetation, or quickly traversed the canopy to a distant site. The dust trail was too diffuse to follow through the tangled understory. The radiocollar would have been an asset. It would have allowed determination of her final position (the daytime retreat). If the dust charge had lasted for the entire night, it would have been possible to go to the final position and backtrack through the pathway to derive information about her movements during the night.

Table 1. - Individual Key Largo woodrats captured in May and June 1985 are listed with their sex, weight in grams, and dates of capture. f = female, m = male, j = juvenile, u = undetermined, rc/dc = radiocollared with dust capsule. Stick mounds, often free-standing, with entrances into the above ground portion, are referred to as large (lg.) stick nests; clusters of sticks associated with underground holes (usually beneath trees), are referred to as small (sm.).

SITE	SEX	WEIGHT (g)	DATES OF CAPTURE	CAPTURE DATA AND COMMENTS
1	f	206	6/17	rotten log pile
2	jf	65	6/15	lg. stick nest
2	jm	69	6/15	lg. stick nest
2	m	180	6/16	sm. stick nest
2	m	189	6/16	sm. stick nest
3	m	233	6/16	feeding station
4	f	140	6/12	lg. solution hole stick nest
5	f	215	6/10	feeding station; lactating
6	m	190	6/17	end of log on ground
7	jm	115	6/8	rock ridge
8	f	u	6/12	feeding station; rc/dc
9	jm	138	6/9	lg. stick nest
11	f	262	6/17	end of log on ground
12	m	195	6/11	rock ridge
13	f	182	6/14	beside fallen branch
13	f	153	6/15	beside fallen log
13	f	160	6/16	tipped wind-throw
15	f	202	6/15	rock ridge
15	jf	65	6/15	rock ridge
15	jm	63	6/15	rock ridge
16	f	145	6/14	lg. stick nest
17	f	126	6/13	lg. stick nest
18	m	241	6/7	hole in root mound
19	f	118	5/23	hole in root mound
19	jf	106	5/24	hole in root mound
19	m	214	5/24	hole in root mound
19	jf	109	5/30	hole in root mound
19	jm	137	5/30	hole in root mound
19	f	118	5/31	hole in root mound
19	jf	103	5/31	hole in root mound
20	f	u	5/19,30, 6/3,12	1 lg., 3 sm. stick nests; rc/dc
20	f	u	5/19	
20	jm	u	5/29	sm. stick nest
20	f	164	5/30	sm. stick nest; lactating
20	f	119	5/30	sm. stick nest; lactating
20	f	232	5/30	sm. stick nest; old
20	f	195	6/6	sm. stick nest
20	m	u	6/9,10,12	sm. stick nest
20	f	185	6/11,12	sm. stick nest
22	f	211	5/23	lactating
22	m	224	5/23	hole in root mound
23	f	97	6/8	hole under tree roots
24	f	129	5/31,6/1,4	lg. stick nest under wind-th[illegible]w
24	m	214	6/1;5	hole under tree roots

Table 1. - continued, p. 2

24	f	284	6/5	tipped wind-throw
25	f	251	5/30,6/1,4,5	lg. stick nest/root mound
25	jf	103	5/30,31,6/1,4,5	lg. stick nest/root mound
25	jf	97	5/31,6/4,5	lg. stick nest/root mound
26	jf	96	6/7	hole in tree root mound
29	f	155	6/9	lg. hole under tree roots
30	f	140	5/14,18,19,20	three locations (1); rc/dc
33	f	180	6/7	hole by tree roots; lactating
34	f	227	6/10	lg. stick nest under wind-throw
37	m	254	6/7	hole under tree roots
38	m	255	5/18	lg. stick nest
38	m	232	5/19	lg. stick nest
38	f	153	5/20	lg. stick nest
41	jm	138	6/16	sm. stick nest under wind-throw
44	u	u	5/11	hole under tree roots

	TOTAL CAPTURES OF INDIVIDUALS	TOTAL RECAPTURES	TOTAL CAPTURES
Males	13	3	16
Females	30	12	42
Juvenile males	7	0	7
Juvenile females	8	6	14
Sex undetermined	1	0	1
GRAND TOTALS	59	21	80

1 - Captured once at a feeding station, twice at a wind-throw, once at a small stick nest.

Table 2: Individual Key Largo cotton mice captured in May and June 1985 are listed with their sex, weight in grams, and dates of capture. f = female, m = male, j = juvenile, u = undetermined, bl = parasitized by bot fly larva. Large (lg.) and small (sm.) stick nests are defined in Table 1.

SITE	SEX	WEIGHT(g)	DATES OF CAPTURE	CAPTURE DATA AND COMMENTS
3	f	21	6/16	sm. hole under tree roots
5	m	24	6/10	
5	f	29	6/11	hole under tree roots
5	f	29	6/11	hole under tree roots
6	f	22	6/17	
7	m	24	6/8	hole under tree roots
8	f	u	6/12,13	lg. solution hole stick nest
9	f	u	6/8	hole under tree roots
9	m	29	6/8	hole under tree roots
9	m	26	6/9	hole under tree roots
10	f	31	6/7	tipped wind-throw
11	f	35	6/17	pregnant
12	u	u	6/10	rock pile
14	m	u	5/10	feeding station
14	f	u	5/11	tree root mound
14	m	u	5/11	tree root mound
15	f	27	6/16	
16	m	u	6/13	holes by fallen logs
16	m	24	6/14	holes by fallen logs
17	f	u	6/13	lg. stick nest
18	m	29	6/7	hole under tree roots
19	m	28	5/30	medium hole at tree base
19	jm	19	5/30	feeding station
19	jm	19	5/30	feeding station
19	f	27	5/31	hole by tree roots
20	f	20	5/15,16	lg. stick nest; lactating
20	f	25	5/19	lg. stick nest
20	f	u	5/20	lg. stick nest
20	f	16	6/6	sm. stick nest; lactating
20	m	34	6/10	sm. stick nest; bl
22	jf	16	5/22	hole under tree roots
22	f	18	5/23	hole under tree roots
22	f	18	5/23	hole by tree roots; lactating
23	f	16	6/8	hole under tree roots
23	f	18	6/8	hole under fallen log
24	f	19	5/30	lg. hole under tree roots
24	m	30	5/30	lg. hole under tree roots
24	f	30	5/31	tipped wind-throw; lactating
24	m	28	5/31, 6/1,4,5	hole under tree roots
24	f	24	6/1,4	tipped wind-throw; bl
24	m	26	6/1	hole under tree roots; bl
24	m	38	6/4,5	lg. hole under tree roots
25	m	23	5/31	hole in tree root mound
26	f	24	6/7	base of wind-throw
26	m	26	6/7	holes under tree roots
26	m	22	6/7	hole in tree root mound

Table 2. - continued p. 2

27	f	27	6/1,5,6	hole under stump; bl
27	f	26	6/1,4,5	hole under tree roots
27	f	20	6/1,4,5	hole under tree roots; pregnant
27	m	21	6/1,4,5,6	hole under tree roots
27	jm	u	6/1	hole under tree roots
27	f	25	6/4	hole under tree roots; bl
27	m	28	6/4,5	hole under tree roots; bl
27	jf	u	6/5	hole under tree roots
28	f	24	6/1,4,5	hole under tree roots
28	m	26	6/1,4	hole under tree roots
28	jm	19	6/4,6	hole under tree roots
28	u	u	6/5	hole under tree roots
29	m	19	6/8	hole under tree roots
29	m	21	6/8	hole under tree roots
29	m	24	6/8	hole under tree roots
29	f	24	6/9	hole under tree roots (1)
29	m	24	6/9	hole under tree roots
29	m	19	6/9	hole under tree roots
29	m	16	6/9	lg. hole under tree roots
30	m	30	5/14	hole at base of tree
30	m	25	5/14	hole under tree roots
30	m	29	5/16	hole under tree roots
30	m	35	5/16	hole under tree roots
30	m	26	5/18	hole under tree roots
30	m	22	5/18	hole under tree roots
30	m	24	5/18	hole under tree roots
30	m	26	5/19	hole under tree roots
30	ju	u	5/20	tipped wind-throw
30	ju	u	5/20	tipped wind-throw
30	ju	u	5/20	tipped wind-throw
30	ju	u	5/20	tipped wind-throw
31	f	26	6/4,5	hammock/burn ecotone
31	m	32	6/4,5	hammock/burn ecotone
32	f	22	5/31	hammock/burn ecotone
32	m	24	5/31	hammock/burn ecotone
32	f	20	6/1	hammock/burn ecotone (2)
32	m	28	6/1	hammock/burn ecotone
32	m	32	6/1	hammock/burn ecotone (3)
33	f	21	6/7	hole under tree roots
34	m	u	6/7	hole under tree roots
34	f	27	6/10	hole under tree roots
35	m	29	5/23	bracken/Jamaica dogwood
35	u	u	5/24	bracken/Jamaica dogwood
35	f	34	5/30	bracken/Jamaica dogwood
35	m	29	5/31	bracken/Jamaica dogwood
35	f	22	6/1	bracken/Jamaica dogwood (4)
36	f	23	6/4,5	bracken (4)
36	m	27	6/4,5	bracken (5)
36	f	21	6/5	bracken
37	f	30	6/7	hole under tree roots; pregnant
37	f	30	6/7	hole under tree roots; pregnant
37	jf	13	6/7	hole under tree roots

Table 2. - continued, p. 3

38	jf	21	5/16	
38	m	35	5/16	lg. hole under tree roots
38	m	22	5/18	lg. hole under tree roots
38	u	u	5/20	by C. guanhumi hole
38	u	u	5/20	lg. hole under tree roots
39	f	25	5/30, 6/1	fallen wind throw; lactating
39	m	28	5/30	hole at base of tree
39	m	18	5/31	pile of bark
39	m	28	5/31	pile of bark
39	u	u	6/1	pile of bark
40	jm	15	6/7	feeding station
40	f	21	6/9	feeding station
40	m	27	6/10	holes in rock pile
40	jm	17	6/10	feeding station
40	jm	21	6/10	feeding station
41	f	19	6/5,6	sm. hole at tree base
41	m	25	6/5	tipped wind-throw
41	f	37	6/11	lg. stick nest
41	m	39	6/11	lg. stick nest
41	m	u	6/11	lg. stick nest
41	m	u	6/12	lg. stick nest
41	m	u	6/13	lg. stick nest
41	m	28	6/15	lg. stick nest
41	m	30	6/16	lg. stick nest
43	m	21	5/17	bracken
43	m	32	5/18	bracken
43	u	u	5/20	bracken
44	m	u	5/11	hole under tree roots

	TOTAL CAPTURES OF INDIVIDUALS	TOTAL RECAPTURES	TOTAL CAPTURES
Males	59	11	70
Females	45	15	60
Juvenile males	7	1	8
Juvenile females	4	0	4
Sex undetermined:			
adult	7	0	7
juvenile	4	0	4
GRAND TOTAL	126	27	153

1 - recapture of female collected at Site 28
2 - recapture of female collected at Site 31
3 - recapture of male collected at Site 31
4 - recapture of 22 g female collected at Site 32
5 - recapture of 28 g male collected at Site 32

Table 3. - Individual hispid cotton rats and black rats captured in May and June 1985 are listed with some additional capture data. cr = cotton mouse, br = black rat, f = female, m = male, j = juvenile, u = undetermined.

SITE	SPECIES	SEX	CAPTURE DATE	COMMENTS
2	cr	u	June 15	by stick nest
7	cr	jm	June 8	rock pile
8	cr	2m	June 12	tree roots
11	br	jm	June 17	hammock floor
13	br	m	June 10	hole hammock floor
13	br	u	June 12	hammock floor
22	cr	m	May 22	tree root mound by dirt rd
22	cr	u	May 23	tree root mound by dirt rd
31	cr	f	June 4	hammock/burn ecotone
31	cr	2f	June 5	hammock/burn ecotone
32	cr	f	June 1	hammock/burn ecotone
36	cr	3f	June 4	bracken
36	cr	2m, u	June 5	bracken
43	cr	f, m	May 17	bracken
43	cr	f, u	May 18	bracken
43	cr	f, 3m	May 19	bracken
43	cr	3u	May 20	bracken

Table 4. - Accumulated trap-nights at 11 sites on Key largo.

	TRAP-LINE SITES										
	45	44	14	20	30	38	43	21	22	32	35
May 8	30										
9	30	20	10								
10	30	20	10								
11											
12											
13				10	20	10	10				
14				10	20	10	10				
15				10	20	10	10				
16				10	20	10	10				
17				10	20	10	10				
18				10	20	10	10				
19				10	20	10	10				
20											
21								9	20		
22									40	9	10
23										9	10
24											
25											
26											
27											
28				9							
29				9						9	10
30										9	10
31										9	10
June 1											
2				4						9	10
3											
4											
5				3							
6				5							
7				5							
8				10							
9	10			10							
10	10			10							
11	10			10							
12	9										
13	10										
14	12										
15	12										
16	12										
17	12										
18	12										
Total trap-nights	199	40	20	148	40	70	70	9	60	81	90

Table 5. - Accumulated trap-nights at 11 sites on Key Largo.

	TRAP-LINE SITES										
	19	24	25	39	41	27	28	10	26	29	40
May 22	10										
23	10										
24											
25											
26											
27											
28											
29	14	10	10	10							
30	14	10	10	10							
31	14	10	10	10	27	10	10				
June 1											
2					27						
3		10	10		27	10	10				
4		10	10		27	10	10				
5					27	10	10	10			
6								10	10	10	10
7										10	10
8										10	10
9											10
10					10						
11					10						
12					10						
13					10						
14					10						
15					10						
Total trap-nights	62	50	50	30	195	40	40	20	10	30	40

Table 6. - Accumulated trap-nights at 12 sites on Key Largo.

	TRAP-LINE SITES											
	31	36	18	33	34	37	7	9	23	5	12	13
June 3	10	10										
4	10	10										
6			10	10	10	10						
7					10		8	10	10			
8					10			10		10		
9					9					10	10	10
10											10	9
11												10
12												8
13												8
14												10
15												10
16												10
17												10
Total trap-nights	20	20	10	10	39	10	8	20	10	20	20	85

Table 7. - Accumulated trap-nights at 11 sites on Key Largo.

	TRAP-LINE SITES										
	8	4	16	17	15	2	3	6	11	1	42
June 11	10	10									
12	4	10	10	10							
13	4	10	10								
14	4	10			10	10					5
15					10	10	10				5
16								10	10	10	
17										10	
18										10	
Total trap-nights	22	40	20	10	20	20	10	10	10	30	10

Table 8. - Trap-night success for Key Largo woodrats and cotton mice at 45 sites in May and June 1985.

TRAP-LINE SITE	TOTAL CAPTURES OF WOODRATS	TOTAL CAPTURES OF COTTON MICE	TOTAL TRAP-NIGHTS	TRAP-NIGHT SUCCESS: WR/CM
1	1	0	10	.10 / .00
2	4	0	20	.20 / .00
3	1	1	10	.10 / .20
4	1	0	40	.03 / .00
5	1	3	20	.05 / .15
6	1	1	10	.10 / .10
7	1	1	8	.13 / .13
8	1	2	22	.05 / .09
9	1	3	20	.05 / .15
10	0	1	20	.00 / .05
11	1	1	10	.10 / .10
12	1	1	20	.05 / .05
13	3	0	85	.04 / .00
14	0	3	20	.00 / .15
15	3	1	20	.15 / .05
16	1	2	20	.05 / .10
17	1	1	10	.10 / .10
18	1	1	10	.10 / .10
19	7	4	62	.11 / .07
20	15	6	148	.10 / .04
21	0	0	9	.00 / .00
22	2	3	60	.03 / .05
23	1	2	10	.10 / .20
24	6	12	50	.12 / .24
25	12	1	50	.24 / .02
26	1	3	10	.10 / .30
27	0	18	40	.00 / .45
28	0	8	40	.00 / .20
29	1	7	30	.03 / .23
30	4	12	40	.10 / .30
31	0	4	20	.00 / .20
32	0	5	81	.00 / .06
33	1	1	10	.10 / .10
34	1	2	39	.03 / .05
35	0	5	90	.00 / .06
36	0	5	20	.00 / .25
37	1	3	10	.10 / .30
38	3	5	70	.04 / .07
39	0	6	30	.00 / .20
40	0	5	40	.00 / .13
41	1	10	195	.01 / .05
42	0	0	10	.00 / .00
43	0	3	70	.00 / .04
44	1	1	40	.03 / .03
45	0	0	199	.00 / .00
COLUMN TOTALS	80	153	1848	.04 / .08

DISCUSSION

Woodrat Distribution

Although most woodrats have been collected on North Key Largo, they have been taken as far south as Rock Harbor (Schwartz, 1952). Additional specimens were collected when Sherman (1955) described the new subspecies but the locality data for the specimens are not specific: only "Key Largo, Monroe Co., Florida".

Their present distribution is thought to be restricted to hammocks north of the junction of US 1/S-905 (Brown, 1978; Hersh, 1978; Humphrey and Barbour, 1979). Most of the hammock on the southern end of North Key Largo is less mature than that at the north, and has been suspected to be unsuitable for the species (Brown, 1978; Humphrey and Barbour, 1979). Few stick nests are present on the southern end. Schwartz (1952) suspected however, that the two specimens collected at Rock Harbor may have been living in "cracks and holes in limestone", as he found no stick nests in the area. As a result of the radiotelemetry/dust capsule tracking, it is now known that woodrats use holes as refugia, and perhaps because stickpiling becomes superfluous, leave scant evidence of their presence. However, a stick nest was seen (under an old still), on Port Bougainville in 1984 (pers. obs.). A small stick nest was also found in the southern end of the Garden Cove hammock (ocean side), but the nest occupied by

the woodrat captured at the site was in a neat stack of rotted logs. Presence was indicated by a cluster of four to six sticks poking out from the log pile and cleared ground around the pile.

The most current map indicating the distribution and abundance of the Key Largo woodrat was compiled by Humphrey and Barbour (1979). Although no attempt was made to estimate density in the spring/summer of 1985, it is possible to update the distributional information they presented. Woodrats do occur in hammocks L2/4, L2/5, and L1/7, even though there are fewer stick nests present. Much less of hammock L1/6 is burned than was indicated, and woodrats also inhabit the northern portions of this hammock. Since the search image for woodrat sign has been broadened by results from the tracking, it is likely that they will be found in additional localities. It is critical that small stick clusters, holes, and scat piles, as well as stick nests, are recognized as woodrat sign by those involved in decisions regarding land-use.

In hammock L2/7, south of the the US 1/S-905 junction and the Ocean Isle Estates development, Humphrey and Barbour (1979) reported no stick nests. No stick nests or other indications of woodrat presence were found this spring during a walking survey; traps were not set. A trap-line was set in a hammock slightly further south, L2/8. Although more trap-nights were spent here than in any other locality, and the habitat appeared suitable for woodrats, none was collected.

It is not clear what would cause the range to terminate at Garden Cove. In 1970 they were introduced (Brown and Williams, 1971) and successfully colonized (Hersh, 1978; pers. obs., 1984) Lignum Vitae Key, well south of the known range. If they did once occur on southern Key Largo it is possible that they were extirpated by land clearing. All of Key Largo has been previously cleared (Karen Achor, pers. comm.), much of the north less recently. Absence of woodrats might be caused by inefficient dispersal due to limited individual home range, vulnerability to predatation, or that restocking southern areas is sequential from the north. They may not have yet been able to cross the boundary formed by the Ocean Isle Estates development, with its associated canals and borrow pits, to reach suitable portions of recovered L2/7 to the south. I am not confident that the woodrats are absent from hammocks south of the presently known range; further trapping will be conducted.

Cotton Mouse Distribution

Historically, cotton mice were known from Planter, near Tavernier (Layne, 1974); in recent years they have not been captured south of the US 1/S-905 junction. The southernmost locality in which they were taken by Schwartz (1952) was in a locality listed as 12 miles northeast of Rock Harbor. This too is above the junction, slightly north of the southernmost locality, hammock L2/4, in which they were taken this spring (Site 44; Figure 2). I suspect they occur further south than

L2/4, although trapping was suspended before they were collected. Signs of cotton mice - characteristic leaf-covered holes - were present at Garden Cove. Further trapping will be conducted in southern areas to define the present limit of their range; it may still extend past the junction of US 1/S-905.

Woodrat Habitat Use

Key Largo woodrats were found in hammocks with varying levels of maturity, occupying several types of refugia. Trapping data (Table 1) show them associated with large stick nests in 26 of the total captures, small stick nests in 17, wind-throws in nine, tree root mounds in 22, holes under tree roots in seven, and rock ridges in five. In 17 of the captures at wind-throws or tree root mounds, large or small stick nests were also present at the site. This means, however, that of the captures near possible refugia, 31% were by holes with no stick nests nearby. It appears from this and tracking data that woodrats on Key Largo are not dependent on stick nests for shelter.

Although stick nests were not a prerequisite for woodrat habitation of an area, there usually was some evidence of stick piling somewhere on an individual's home range. In several cases this was limited to three or four sticks, arranged in a lattice, around the entrance to a burrow, partially covering a smaller hole, or leaning against a tree or fallen log. Sometimes several sticks or leaves protruding from a pile of rocks was the only indicator of their presence. This was the case at Site 12,

and seen at Sites 15 and 16. During the course of the radiotelemetry/dust tracking, the female woodrat from Site 30 added a delicate frame of three or four twigs to the base of the wind-throw she occupied (nest 1; Figure 5). At this locality, and several others, fresh stick additions were noted after rainstorms, and it seemed as though there could be a relationship between the two. Hamilton and Whitaker (1979) commented that stick nests of Neotoma floridana were "sufficiently well knit to be waterproof". Perhaps the N. f. smalli were responding to leaks.

In the first phase of the study no attempt was made to estimate density of the animals. However, trap-night success (Table 8), and number of woodrat-sized holes per unit area, usually gave an indication of relative abundance at different sites. Using this indicator, it appears that the number of stick nests was more dependent on the type of habitat than the number of woodrats. In older hammocks (e.g. Sites 19, 22, 23, and 26) they seemed to occupy - in order from most to least - tree root mounds, holes beneath tree roots, wind-throws, small stick nests, and last, large stick nests. Roots may provide superior protection, and be preferentially used in areas where those of older trees have lifted and allowed excavation beneath. Woodrats were easily trapped in these sites even though few or no stick nests were found close by.

In younger hammocks they seemed to rely more on large

stick nests, perhaps because tree roots were poorly developed, and wind-throws less common. Edges of solution holes were often used as sites for the nests (e.g. Sites 4 and 8). Again, judging by trapping success, and the relative density of woodrat-sized entry holes, these areas seemed to have fewer woodrats. Those present lived in the stick nests. If stick nests are less protective than holes under roots, this may explain the observations of Brown (1978), Hersh (1978), and Humphrey and Barbour (1979), that woodrat densities were lower in immature hammock. The decrease in abundance seemed especially noticeable in hammocks that had been plowed as well as cleared (e.g. Site 10). The natural holes in the limestone, and solution holes, had been filled, perhaps limiting shelter.

There is little question that this type of habitat, lacking in natural holes, was improved for woodrats in areas where ridges of loose rock had been created during clearing or filling operations. Woodrats had colonized the northwest edge of the fill pad for the Key Largo Beach and Tennis Club. There were at least two nests in rock piles in a scarified area, directly to the east of the clearing on the Maxwell property, bordering Site 16. The rock piles were more than 30 m from the closest stand of hammock vegetation. Their presence was indicated by a framework made of palm leaves and sticks at one nest, and leaf and stick packing in a side wall of the second. Piles of scats, "infallible evidence that Neotoma is about" (Hamilton and Whitaker, 1979), were present at both nests. Other examples of rock ridge utilization occurred at Sites 4, 8, 11, 12, and 15.

Because woodrats may be present when stick nests are not, and implications that stick nest density may be more a function of habitat type than of woodrat abundance, stick nests should not be used as an index of woodrat density. There is also no generally applicable estimate for relating woodrat number to nest number. Hersh's (1978) figure of 5.6 nests per woodrat cannot be appropriate in localities where several woodrats were captured from one isolated nest (e.g. Sites 15, and 25).

Additional Concerns Involving Woodrats

Still to be evaluated is the effect of continuous versus open canopy on woodrats. Because they are more arboreal than previously suspected (Hersh, 1978), non-continuous canopy present in younger forests may affect their movement. The female that ran up a sapling at Site 13 might have been able to escape to a distant hole if she could have crossed from tree to tree. Also, the effect of black rats on woodrats has yet to be studied. Little is known about the extent of interaction between the species. They were collected together in only two localities during the spring/summer of 1985 (Sites 11 and 13). According to Hersh (1978) trappability of black rats increases in the Autumn, and there may be more opportunity to look at the potential effects of this introduced species then. Continued radiotelemetry/dust capsule tracking studies may provide insight into the effects of both canopy structure and interspecific

interactions.

The effect of land clearing beside habitat occupied by woodrats may depend partly on subsequent plans for the land. A family dwelling, with the usual complement of cats and dogs, might have more effect than a clearing for fifty beehives. Another factor may be the size and proportion of hammock that abuts the clearing. An isolated hectare (about 2.5 acres) of woodrat inhabited hammock might be more strongly impacted by an adjacent clearing than a 20 ha parcel. Small parcels with small woodrat populations would be less resiliant, with less chance of recovery from damage than hammock with a larger pool of individuals. With increasing size of the parcel, the perimeter to area ratio decreases, and it becomes less likely that all woodrats could be extirpated by impacts associated with an adjacent clearing. This increases the possiblity for restocking from unaffected areas of the hammock.

Woodrats have been found inhabiting recently cleared areas. Two stick nests were located on the fill pad of the Key Largo Beach and Tennis Club. Both were on the northwest corner of the marl, where it is about 1 m thick, directly to the east of Site 16. Widely scattered volunteers of canopy trees (poisonwood, gumbo limbo) occured on the pad, but otherwise it was largely vegetated with potato tree, bushy fleabane (Pluchea odorata), and an introduced vine (Colubrina asiatica). One stick nest was under a native palm, amidst 2 m high surrounding vegetation. It lay roughly 20 m from the edge of the pad where

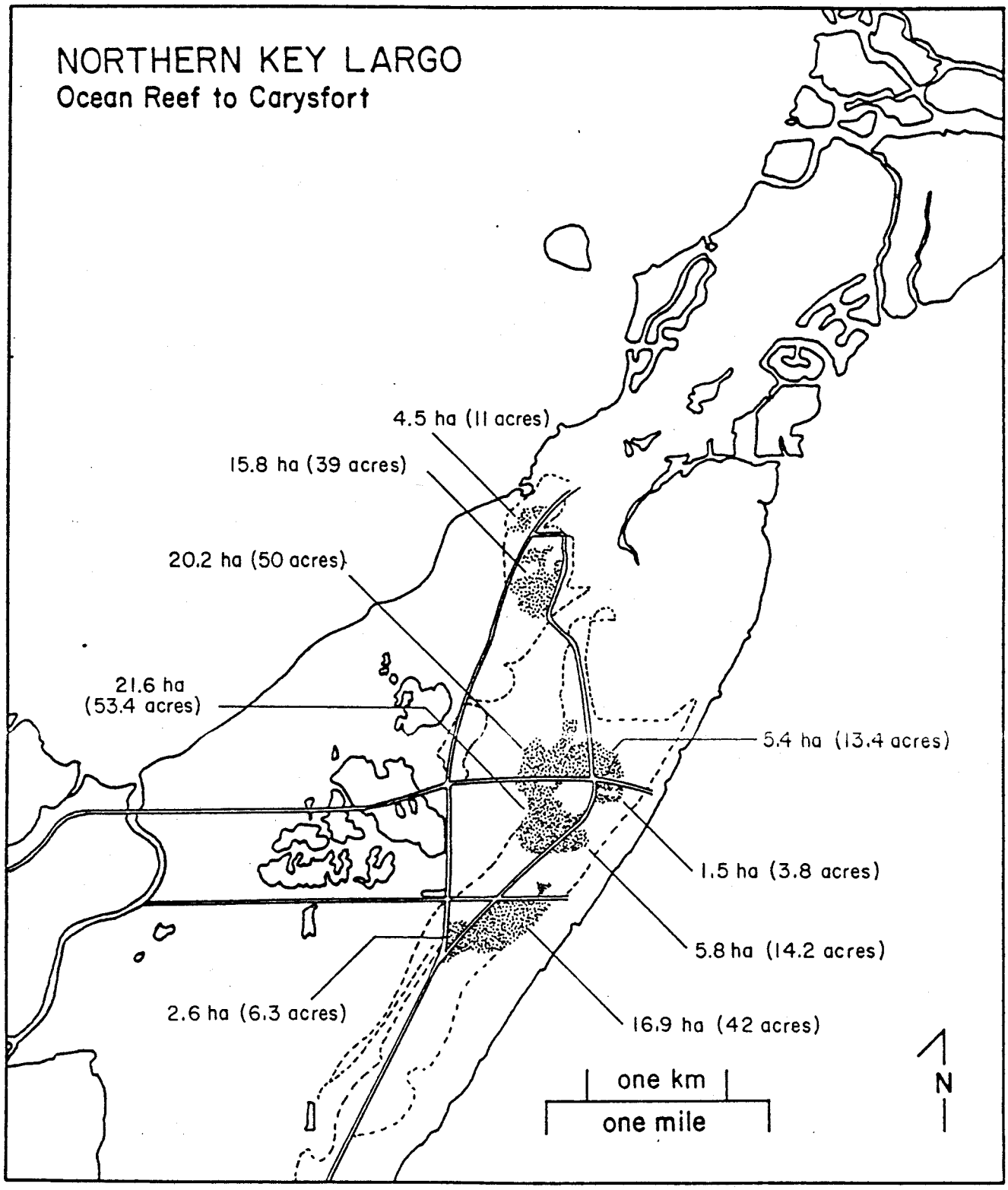
the hammock ended. The other stick nest was further out on the clearing, about 40 m from the closest hammock, under a lone gumbo limbo in a bank of 2 m high vegetation.

Recently burned land, in the early stages of recovery (the first 10 years), does not appear to be frequently used by woodrats. The female tracked at Site 30 ventured into a burn, but no nests or woodrat holes were seen in these areas during the first phase of the study. No woodrats were trapped in burns, though some of the trap-lines were set in them, one or two meters from unburned hammock (Sites 31, 32, and 43). Perhaps they are more vulnerable to predation there; certainly arboreality would be precluded by lack of a canopy. The 280 - 305 ha (700-750 acres) of hammock north of the Missile Base are shown in Figure 7. Of this, 94 ha (233 acres) has been burned (Figure 7). The largest recent fires occurred in hammocks L1/6 in 1975, and in L1/10 a and b in 1977, and L1/11 (Weiner, 1979). If use of these areas is limited it would effectively reduce currently available habitat, north of the missile base, by one third.

Cotton Mouse Habitat Use

Although they were found almost everywhere woodrats were, cotton mice seemed more abundant on the northern end of North Key Largo. It may have been a function of seasonality - trapping on the southern end occurred later - but cotton mice were harder to catch in the less mature stands of hammock typical

Figure 7. - Areas north of the missile base where fires within the last decade have destroyed most mature hammock vegetation. Stippled areas areas represent the 94 ha (233 acres) of burned hammock; dotted lines mark the approximate borders of the unburned hammock.


NORTHERN KEY LARGO
Ocean Reef to Carysfort
4.5 ha (11 acres)
15.8 ha (39 acres)
20.2 ha (50 acres)
21.6 ha
(53.4 acres)
5.4 ha (13.4 acres)
1.5 ha (3.8 acres)
5.8 ha (14.2 acres)
2.6 ha (6.3 acres)
16.9 ha (42 acres)
one km
one mile
N

of the area. From their trapping results, Humphrey and Barbour (1979) concluded that immature hammock is less suitable for the mice. This spring, the highest trap-night success, 0.45 (Table 8), occurred at Site 27 in hammock L1/6. This area was riddled with large and small holes and, interestingly, no woodrats were collected there. It was one of the most mature hammock localities in which trapping was conducted. In several other sites, trap-night success was almost as good () 0.20): Sites 24, 26, 29, 30, 36, and 37. Sites 26 and 29 were as mature as Site 27; Sites 24, 30, and 37 were less so. Site 36 however, where trap-night success was 0.25, was located in the center of a burned area (see site descriptions above). Of the total captures of cotton mice, 14% were in burned areas (Table 2). In the burns, mice were trapped in the runways of cotton rats, typical inhabitants of early successional stages. The runways spread in a network beneath the dead layer of bracken covering the ground. The dead bracken must have provided good protective cover for the cotton mice and cotton rats. Since cotton mice appear more oportunistic, and less dependent on mature hammocks than suspected, the value of the burns should not be ignored.

Of the total number of captures of cotton mice (Table 2), 56% were from holes under roots, root mounds, or beside logs. Often, they were found in association with woodrats. Eleven percent of total mouse captures were near or in stick nests, and at least 5% were by large holes in tree roots. They may use the woodrats' food caches (described by Hersh, 1978), or nest peripherally in the stick nests. Because they were frequently

captured by holes in the middle of the forest floor, and inhabited burned areas with no canopy, it is likely that cotton mice are more terrestrial than woodrats on Key Largo. More information on the degree of association between the two species, their habitat use and resourse partitioning, will result from additional radiotelemetry/dust tracking studies.

Additional Concerns Involving Cotton Mice

Bot fly larvae (probably family Cuterebridae) were seen on five of the mice (none of the woodrats had them). The parasites were large, approximately one-sixth the size of the mice, and located under the skin on the caudo-ventral region, or ventral side of the thigh of the animal. Affected animals appeared relatively unencumbered by the larvae; they ran off as rapidly as animals without them. The parasites were observed at three trap-line sites, 20, 24, and 27, in both hammock and burned areas.

Schwartz (1952) trapped a house mouse, Mus musculus, from a grassy clearing in a Key Largo hammock dominated by wild tamarind. Since these introduced mice are known to occupy a varity of habitats, as it now appears that cotton mice do, there may be some interaction between the two species. However, Mus was not captured in the hammocks of North Key Largo during the first phase of the study; at that time its effect on other rodents was probably insignificant.

General Indications

For Key Largo woodrats and cotton mice, immature hammock may be inferior habitat because it tends to have fewer holes at ground level. Holes are heavily utilized by both species. Habitat in immature hammock seems improved by the presence of loose rock piles and ridges, which when present, are often occupied by woodrats and sometimes cotton mice. If these hammocks are left to mature - 20 to 40 more years - the number of holes should increase as trees increase in size, roots begin to mound, the humus layer thickens, and as continued rainfall etches underground caverns in the limestone (particularly important in the plowed areas). As the trees become larger they will be more apt to lean or topple in high winds and create additional shelter beneath their exposed roots or trunks.

Fires are a natural phenomenon in Florida, as much so as hurricanes. Although the last major fires on North Key Largo were probably caused by humans (Weiner, 1979), doubtless fires have been a part of Key Largo ecology for thousands of years. The animals occurring on the island, especially those that have occupied the island long enough to become distinct taxonomically, have evolved in association with the system. They persist despite sudden, catatastrophic modifications to major portions of habitat caused by fires or hurricanes. The system of hammock destruction/recovery is cyclic. Previous workers have noted the natural re-establishment of canopy trees in recovering burns and

clearings (Humphrey and Barbour, 1979; Weiner, 1979). Both woodrats and cotton mice appear to exploit the cycle. Burned areas may be invaded from surrounding hammock by cotton mice within the first decade after a fire. Woodrats could restock from adjacent hammocks as new canopy forms, and old trees killed by fire gradually lean and fall, creating optimal locations for nest sites beneath their roots and trunks. High winds or hurricanes would have a similar effect in unburned forest. Although it appears that woodrats initially avoid burned areas, as recovery proceeds, the affected habitat would be enhanced for them and cotton mice, because of the leaning and fallen trees. As forest maturation continues, increasing numbers of chambers and holes could be excavated under roots of living trees. As the hammock matures and ages, animal and plant populations should reach some relatively stable upper limit of growth, maintained until the system is jostled by the next natural catastrophe.

In developing a management scheme for the two species we should plan on the inevitability of fires and hurricanes. Since both can occur instantaneously, and temporarily damage large parcels of land, we cannot cluster the animals in a single area on North Key Largo. The most protective strategy is to designate as management areas, mature or maturing hammock along the longest, widest contiguous stretch on North Key Largo. The larger the land allocation the smaller the chance of extirpation by fires or storms. Establishing a continuous management zone enables the natural restocking proccess to occur from unaffected

adjacent hammock as the damaged area recovers.

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I am extremely grateful to Glenn Mitchell, my field assistant, whose fortitude, and good cheer, made the study run effectively. I cannot thank Larry and Shirleen Lawrence enough for their help, enthusiasm, and affection. Karen Achor taught me to recognize the plants I do; I gratefully acknowledge the hundreds of hours of work she did to learn to identify them, and the additional time and knowlege she gave me. Last, I thank Jeff Goodyear for tolerance when I'm gone, and hugs when I get home.

LITERATURE CITED

Brown, L.N. 1978. The Key Largo woodrat. Pp. 11-12 in J.N. Layne (ed.), Rare and Endangered Biota of Florida. Vol. 1, Mammals. Univ. Presses of Florida, Gainesville, 52 pp.

Brown, L.N. and R.L. Williams. 1971. The Key Largo woodrat (Neotoma floridana smalli) and cotton mouse (Peromyscus gossypinus allapaticola) on Lignum Vitae Key, Florida. Florida Nat., 44: 95 - 96.

Hall, E.R. 1981. The Mammals of North America: Second Edition. John Wiley and Sons, Vol. 2: vi + 601 - 1181.

Hamilton, W.J, and J.O. Whitaker. 1979. Mammals of the Eastern United States: Second Edition. Comstock Publishing Associates, Cornell University Press, 346 pp.

Hersh, S.L. 1978. Ecology of the Key Largo Woodrat. M.S. Thesis, Univ. of Miami, Coral Gables, 109 pp.

Humphrey, S.R. and D.B. Barbour. 1979. Status and habitat of eight kinds of endangered and threatened rodents in Florida. Special Scientific Report No. 2. Office of Ecological Services, Fla. State Mus., 17 pp.

Layne, J.N. 1974. The land mammals of South Florida. Pp. 386 - 413 in P.J. Gleason (ed.), Environments of South Florida: Past and Present. Miami Geol. Soc., Memoir 2, 452 pp.

Lemen, C.A. and P.W. Freeman. 1985. Tracking mammals with

fluorescent pigments: a new technique. J. Mamm., 66(1): 134 - 136.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. Amer. Midl. Nat., 37: 223 - 249.

Ruttenber, J. and A. Weiner. 1977. Florida Keys hardwood hammock atlas. National Audubon Soc., blueprint, 11 pp.

Schwartz, A. 1952. The land mammals of southern Florida and Upper Florida Keys. Ph.D. Diss., Univ of Michigan, Ann Arbor, 180 pp.

Sherman, H.G. 1955. Description of a new race of woodrat from Key Largo, Florida. J. Mamm. 36: 113 - 120.

Weiner, A. 1979. The hardwood hammocks of the Florida Keys: an ecological study. M.S. Nat. Audubon Soc./Florida Keys Land Trust.

DENSITY ESTIMATES OF THE KEY LARGO WOODRAT AND COTTON MOUSE USING COMPUTER PROGRAM "CAPTURE"

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ABSTRACT.--Densities of Neotoma floridana smalli and Peromyscus gossypinus allapaticola were estimated in tropical forest on northern Key Largo, Florida, using large, nested trapping grids and probability models from computer program CAPTURE. The assumption of population closure was satisfied, but population density in most grids was nonuniform, requiring use of a model assuming heterogeneous capture probabilities for estimating densities. Three grids near development averaged 3.1 woodrats and 15.5 cotton mice per ha, and three distant from development averaged 12.2 woodrats and 26.9 cotton mice per ha. Extrapolation over the 851 ha of occupied forest suggests total populations of approximately 6,500 woodrats and 18,000 cotton mice.

The Key Largo woodrat (Neotoma floridana smalli) and Key Largo cotton mouse (Peromyscus gossypinus allapaticola) are listed as endangered species by the governments of the United States and the State of Florida. These rodents are endemic to Key Largo, Monroe Co., Florida, and they are

distinct from their mainland relatives (Schwartz 1952a, Sherman 1955, Schwartz and Odum 1957). The nearest modern records of eastern woodrats in peninsular Florida are about 260 km from Key Largo (Sherman 1944), but a post-Columbian specimen (Hershfeld 1968) from a solution pit near Princeton, Dade Co., indicates a former population extending down the Atlantic coastal ridge to a point about 35 km north of Key Largo. No modern hiatus occurs in the range of cotton mice in southern Florida, though (like the woodrat) this subspecies is absent from several keys north of Key Largo (Schwartz 1955b).

Recent conservation action focused partly on these two rodents has included planning of Crocodile Lake National Wildlife Refuge, land acquisition under Florida's Conservation and Recreational Lands program, and preparation of a Habitat Conservation Plan (HCP; Siemon, Larsen & Purdy 1986) designed to accomplish the best of both conservation and development on northern Key Largo. The purpose of this study was to estimate densities of populations of Key Largo woodrats and cotton mice in areas anticipated to be subject to development proposals, to provide data for consultation as provided under Section 10 of the Endangered Species Act. For that purpose, information is needed on the approximate numbers of endangered species that would be impacted by land-use changes. The only prior information on densities of these rodents is provided by Hersh (1981), who estimated a density of 2.2 Key Largo woodrats per ha in a tract of

relatively mature tropical forest, selected as a high-density area on the basis of numerous woodrat nests. On this site Hersh noted little seasonal change in woodrat density from August to May. No data have been published on density of cotton mice anywhere in the species' range.

METHODS

Five study sites were selected in dry tropical hardwood forest, in consultation with county, state, and federal officials, representatives of private landowners, and members of the firm conducting the HCP process. A sixth site, expected soon to come under public ownership, was included as a benchmark site on which measurements may be repeated in the future to monitor population trends.

Design.--The study design (Table 1) was to gather capture-recapture data based on livetrapping with large Sherman traps set at 10-m intervals, baited with rolled oats, and checked daily. Although sample size (the number of animals to be captured and recaptured) was a major concern during the design phase of the work, not enough prior information existed to predefine an adequate sampling effort. In practice, sampling effort was determined partly by statistical requirements and partly by unrelated logistic constraints. Grid size was as large as could be fit within the limits of the size of the area to be trapped and a 2-3 day limit set for deploying the traps (time varied according to difficulty of movement through the vegetation). Duration of the recapture work was determined partly by evidence that

TABLE 1. Descriptions of sampling design and effort used to estimate populations of Key Largo woodrats and cotton mice.

Grid	Location	Dates	Rows and columns	Area (ha)	Trap-nights	Percent traps disturbed	Predator removal
1	Port Bougainville	5-9 May	20 x 17	3.4	1,700	22.1	yes
2	Ocean Forest	26-30 March	20 x 17	3.4	1,700	21.1	no
3	Dillworth-South	6-10 March	20 x 14	2.8	1,400	21.1	no
4	Angler's Club	18-21 April	17 x 17	2.9	1,156	68.9	no
5	Ocean Reef Club	26-30 April	20 x 17	3.4	1,700	4.1	yes
6	Skeet Range	4-8 April	20 x 13	2.6	1,300	15.2	no

most animals had been captured once and partly by the financial cost of the entire sampling period. Grids ranged in size from 13 x 20 to 17 x 20 traps, and hence from 2.6 to 3.4 ha. Grids were run for 5 consecutive days, except in one case where trapping was terminated after 4 days because so few rodents were captured. Rodents captured were individually marked by removing the terminal phalanx of one or two toes and released at the point of capture. A capture history was accumulated for each individual, consisting of dates and grid-coordinates of the traps in which capture occurred.

White et al. (1982) presented guidelines for grid-sampling effort intended for density estimation. (1) Grids should be placed in homogeneous habitat to ensure near-uniform density of animals on the grids. In this study, grids were placed entirely within single-aged stands of tropical hardwood forest, but homogeneity could not be assured for several reasons. At most sites, the narrow extent of the upland usually caused one or more edges of the grids to be near a highway, power line right-of-way, road through the woods, or natural edge of another habitat. Grids were placed so that such discontinuities were at least 10 m away from perimeter traps, but this did not prevent problems with non-uniform density. Additionally, Grid 6 consisted of about one-half young forest and one-half older forest. (2) Grid size should be fairly large; at a minimum, rows plus columns should exceed 25, and 32 is preferred. In

this study, rows plus columns ranged from 33 to 37. (3) Trap spacing should be such that at least 4 traps are located within each animal's home range, and a spacing of one-half the radius of the home range is preferred. On the question of home range size, no data exist for cotton mice. Hersh (1981) reported the average home range of a Key Largo woodrat to be approximately 0.25 hectares, from which a suggested trap interval of 28 m or less is derived. With the 10-m interval used here, the home range of a woodrat would contain approximately 25 traps. (4) The number of animals needed for the intended estimation methods is not easily judged and depends heavily on their capture probabilities and the number of trapping occasions. In general, when trapping is done for 10 days or fewer, the sample should be at least 20 animals and capture probability should be at least 0.3 if the sample is less than 100. Initial capture probabilities were high in this study--generally about 0.5. In 9 of 12 cases, sample size was adequate according to this guideline. In the other 3 cases, obtaining a precise or unbiased estimate was improbable. (5) the recommended number of trapping occasions is 5, and it should not be much longer if population closure is not certain.

Mortality.--On all grids, some traps were disturbed each night by large mammals. This had two undesirable effects--reduction of the number of traps open for rodent capture and presumed predation of some rodents found in the

APPENDIX B

TECHNICAL REPORT NO. 14.

STATUS SURVEY OF THE SCHAUS SWALLOWTAIL IN FLORIDA IN 1984

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The National Park Service staff at Biscayne National Park were of inestimable help during the 1984 survey work, especially Superintendent James A. Sanders who issued a permit to work on the butterfly throughout the Park and who provided boat transportation and ranger assistance at all times; Mrs. Lorrie Sprague, Research Management and Terrestrial Section Chief, who accompanied and assisted us on all trips; and Miss Nancy Douglass, Seasonal Park Aide, who assisted us on not only our trips but made many additional trips on Elliott Key to census the Schaus Swallowtail population for us.

H. Franklin Percival (Florida Cooperative Fish and Wildlife Unit at the University of Florida) ably coordinated administration of the contract among the U.S. Fish and Wildlife Service, the Florida Game and Fresh Water Fish Commission, the Department of Zoology at U.F., and the School of Forest Resources and Conservation at U.F., to insure the successful completion of the project. His help was invaluable in all respects.

The Florida Game and Fresh Water Fish Commission (Don Wood, endangered species coordinator) kindly granted a permit to handle the Schaus Swallowtail adults briefly during the 1984 field surveys.

ABSTRACT

The purpose of this research was to determine the 1984 population status and geographic distribution of the Schaus Swallowtail butterfly, Papilio (Heraclides) aristodemus ponceanus Schaus, a large and colorful endemic insect in south Florida that is currently on the United States List of Endangered Species and appears to be close to extinction. Its range has steadily declined during the past century. Intensive surveys were carried throughout the Florida Keys and the south Florida mainland to determine the location of extant colonies of the butterfly species and its larval food plants, to determine approximate population sizes, and make ecological observations on its population biology.

The Schaus Swallowtail was at extremely low population levels in 1984. On northern Key Largo, only one adult Schaus was observed. In Biscayne National Park, the total population size was estimated to be thirty adults on Elliott Key, twenty-four adults on Old Rhodes Key, and sixteen adults on Totten Key. The adult flight period extended from the first week of May to mid June. No eggs or larval instars were found from May to September 1984, despite intensive surveys. The larval foodplants, torchwood (Amyris) and wild lime (Xanthoxylem), were present in good numbers in the four recorded adult population areas and were found elsewhere in many hammocks on the Keys and mainland where ponceanus does not presently exist.

The occurrence of the butterfly on northern Key Largo (Hammock 13-14 boundary) in 1984 is of special interest because it was not found on Key Largo in intensive 1980 and 1981 surveys

(U.S. Fish & Wildlife Service, 1982). Apparently, a colony has been persisting there since the Schaus Swallowtail's last peak of abundance in 1971-1972.

INTRODUCTION

The Schaus Swallowtail butterfly (Papilio (Heraclides) aristodemus ponceanus Schaus) is considered one of the rarest resident butterflies in the United States and is listed as endangered by both the State of Florida and the federal government. It is Florida's foremost endemic butterfly, being known historically only from the southeastern tip of the Florida peninsula and portions of the Florida Keys.

The present population status and present distribution of the butterfly have been uncertain since the last surveys carried out in 1980 and 1981 (U.S. Fish & Wildlife Service, 1982). The overall trends in its historic range and numerical abundance in the last eighty years have been in the direction of decline. It has not been recorded from the mainland since 1924, and from the 1940's to the 1970's, it has been found only on two of the middle and upper Florida Keys and in Biscayne National Park.

The ecological and evolutionary reasons for the limitation of the range of the Schaus Swallowtail butterfly to only a small fraction of its potential range are not understood. Habitat alteration by urban development is believed to have been the primary cause of extermination of the species from the Florida peninsula and is currently threatening the important hardwood hammock habitat for the species on Key Largo. Widespread aerial application of insecticides, overcollection, and natural weather factors have also been implicated in the severe range constriction and population decline during this century.

The U.S. Fish and Wildlife Service (USF&WS) determined that a status review was necessary in 1984 in order to establish the present distribution and relative abundance of the Schaus Swallowtail butterfly in Florida. In 1980 and 1981, the Florida Game and Fresh Water Fish Commission (FG&FWFC) conducted research on the historic and current distribution of the species. In order to complete the survey (published as U.S. Fish & Wildlife Service, 1982) and update the knowledge on the status of the species, the present investigator, in cooperation with the FG&FWFC, the National Park Service, the USF&WS, and the Florida Cooperative Fish and Wildlife Research Unit, conducted surveys during 1984 under the support of the USF&WS to determine the current distribution and relative abundance of the species.

The results of this study should provide information enabling effective management planning and actions, and the identification of areas for increased attention as regards future steps and research to assure the survival of this large, distinctive tropical species in the United States fauna.

METHODS AND RESEARCHERS

Ground surveys were conducted within the butterfly's known recent range, and appropriate hammock habitats outside that range, during the reported usual flight and breeding season (May-June) and subsequent months (July-August-September) to check for a possible second brood. Special attention was paid to the extant hammock habitat on the keys in Biscayne National Park, Key Largo, and Lower Matecumbe Key, the only reported population areas for the Schaus Swallowtail since 1940 (Figure 1). Potential Schaus Swallowtail habitat on the other keys and on the mainland north to Miami and Fort Lauderdale and west into Everglades National Park were searched for previously undetected populations. Transects were established in search areas and distribution surveys were conducted on foot by at least two observers during all daylight hours when normal flight activity would be expected. Additional examination of the larval host plants was made for eggs, larvae, and pupae as indicators of established breeding colonies. Where butterflies were found, information was recorded on the exact locations, wing condition ("age") of adults, if they were netted, sex of adult if identified, and habitat use by the butterfly while under observation.

These surveys were started on May 3 and continued at intervals through September 23, 1985. They were conducted by at least two field workers, the principal investigator (Thomas C. Emmel, Professor of Zoology and Director of the Division of Lepidoptera Research at the University of Florida) and an experienced research assistant (James L. Nation, Jr. of the

Department of Zoology of U.F.). In Biscayne National Park, the survey work was very substantially helped by the participation of Mrs. Lorrie Sprague, Research Management and Terrestrial Section Chief (National Park Service), and Miss Nancy Douglass, Seasonal Park Aide. In addition, Miss Douglass conducted twelve weekly or more frequent surveys on Elliott Key from May 18 through August 7, to ascertain the Schaus population's flight period at times that the other investigtors could not be present.

Because of the extremely low population numbers of the adults in 1984, no capture-mark-recapture studies per se were performed on the butterfly. It was felt that the usual paint or dye marking procedures employed in butterfly population studies entailed some risk and were not necessary with such reduced densities. Natural wing damage on each specimen proved to be sufficiently distinctive to identify the butterflies individually upon recapture. Each butterfly was gently netted, examined for several seconds in the hand to record wing condition, sex, and other data, and then released promptly. No injury was incurred by any specimen.

In the survey for immature stages in the Schaus' life cycle, torchwood and Xanthoxylem (wild lime) trees were visually searched from ground level up to about eight feet above the ground. Searching was conducted during daylight hours, and canopy-level foilage of host plants could not be searched; it is quite possible that nocturnal feeding and preferential oviposition on tree-top foliage of torchwood lessened the chances of observing immature stages during this year of extremely low population levels.

RESULTS

STATUS IMMEDIATELY PRIOR TO 1984:

The Schaus Swallowtail, Papilio (Heraclides) aristodemus ponceanus Schaus, has always been confined to the south Florida area, with its northern limit near Miami (described as a new species from there by Schaus in 1911) and its normal southern limit somewhere in the upper keys (from Lower Matecumbe Key north, with only several records from the lower keys, including Key West). The primary host plant, Torchwood (Amyris elemifera), however, occurs in hammocks throughout the lower and upper keys, and on the Atlantic Coast of Florida's mainland north past Miami to Volusia County (Little, 1978). The secondary host plant, Wild Lime (Xanthoxylum fagara), which was first discovered to be a host by Rutkowski (1971), occurs in all the preceding areas and northward to central Florida, as well as south (with Torchwood) into the Bahamas, the West Indies, and Central America (Little, 1978). The ecological and evolutionary reasons for the limitation of the range of the Schaus Swallowtail butterfly to only a small fraction of this potential range are not understood (U.S. Fish & Wildlife Service, 1982). Habitat alteration by urban development is believed to have been the primary cause of extermination of ponceanus from the Florida peninsula, and as noted earlier, is currently threatening the important hardwood hammock habitat for the species on Key Largo. However, habitat destruction in most of the lower keys was not extensive enough between the late 1940's and 1970 to explain the near-sudden absence of the butterfly from those areas at that time. Widespread aerial application of

insecticides for mosquito control by Monroe County, overcollecting by commercial and amateur lepidopterists, and natural weather factors have also been implicated in the severe range constriction and population decline of ponceanus during the recent part of this century (U.S. Fish and Wildlife Service, 1982).

In 1980 and 1981, the Florida Game and Fresh Water Fish Commission conducted research on the historic and the current distribution of the subject species (published as U.S. Fish and Wildlife Service, 1982). In those years, the known breeding colonies of Schaus Swallowtail were restricted to two islands (Old Rhodes and Elliott keys) in Biscayne National Park and one small $100m^2$ area on northern Key Largo in 1980 (three first-instar larvae found on May 27, 1980, but no evidence of breeding found there in 1981). Adult numbers were low in the Park in 1980, and perhaps even lower in 1981. The total observed population on Elliott Key in 1981 was not more than about ten adults (eight observed from May 13 to July 8 by Loftus, and ten observed on May 17 by Krizek). The Torchwood leaf production may have been retarded by a prolonged drought in southern Florida during early to mid-1981. Several areas in southern Biscayne National Park and south to northern Key Largo that could have supported Schaus Swallowtails were not searched in those years (USF&WS, 1982). On May 18, 1982, Covell (1982) informally surveyed ponceanus on Elliott Key in Biscayne National Park and recorded thirty-six sightings, saying also that the species seemed to be "up" in numbers from his previous experience. No other surveys have been reported for 1982 or 1983.

STATUS SURVEY RESULTS FOR 1984:

KEY LARGO:

One small fresh ponceanus, probably a male, was seen on Key Largo (Figure 2) one-half mile south of the Carysfort Yacht Club on May 5 at 10:00 a.m. on a clear warm day. It was flying across an open area, having just left a hammock margin at the eastern end of the border between Hammock 13 and 14 in the Key Largo Beach and Tennis Club property. Two large male Papilio cresphontes were netted here in fresh condition between 9:30 and 10:30 a.m. on this date, along with many pierids, nymphalids and lycaenid butterflies. The entire area of northern Key Largo, both west and east of Highway 905 and north to the Ocean Reef Club entrance, was checked on this same date and no further specimens of ponceanus were seen.

The same areas were checked again on May 7-8 with no discovery of further ponceanus. On June 2-3 and on later visits in June, August and September, the entire northern half of Key Largo was checked intensively and the southern half less intensively. No ponceanus adults were found on these dates; however, both male and female cresphontes in fresh condition were seen and netted. Large numbers of young torchwood and wild lime food plants were found in good condition in mature hammock areas across northeastern Key Largo and as far south as the junction of Highway 905 and U.S. 1. No ponceanus immature stages were found on these dates. Large numbers of pierid, nymphalid and lycaenid butterfly species were found throughout Key Largo in June, August,

and September under excellent weather conditions for flight; few butterflies, however, were observed here in May.

THE FLORIDA KEYS SOUTH OF KEY LARGO

During the period of May 5-11, 1984, a comprehensive survey was conducted throughout the Florida Keys from Key Largo south to Key West. The purpose of this intensive survey during the recorded peak of the usual annual ponceanus flight period was to ascertain whether any populations of ponceanus were present in these former areas of its historic range. The following Keys were checked intensively:

South Key Largo
Plantation Key
Windly Key
Upper Matecumbe Key
Lower Matecumbe Key
Fiesta Key
Long Key
Conch Key
Duck Key
Grassey Key
Pidgeon Key
Little Duck Key
Missouri Key
Ohio Key
Bahia Hondo Key

West Summerland Key

Big Pine Key

Little Torch Key

Middle Torch Key

Ramrod Key

Summerland Key

Cudjoe Key

Sugarloaf Key

Park Key

Lower Sugarloaf Key

Saddle Bunch Keys

Big Coppitt Key

Rockland Key

Stock Island

Key West

Specific comments on certain of these areas follow:

(1) UPPER MATECUMBE KEY:

Some hammock patches were present here, despite the heavy strip development around Mile Marker 81. In the specifically-suitable roadside-park-area hammock to the west side of the highway, we found no signs of torchwood or wild lime food plant or of the butterfly. On side roads off to the east, there was tall hammock near the Green Turtle Inn but no sign of ponceanus or even of Liguus tree snails (which are usually a good indicator of undisturbed hammock)

(2) LOWER MATECUMBE KEY:

The south end and middle portion of Lower Matecumbe Key had several lot-sized hammock areas between the houses and urban developments. We checked several hammock areas here but found no ponceanus. The Giant Swallowtail Papilio cresphontes was reasonably common on Lower Matecumbe Key in the Columbus Drive area. This key, where the butterfly once occurred (until at least 1949, and possibly to 1964), has extensive housing and business development throughout its length and there appears to be little chance the butterfly could survive here today.

(3) LONG KEY:

Of all the keys accessible from the highway in the lower Florida Keys, Long Key State Recreation area (along the nature trail) seem to provide the geographically closest potential habitat to Key West, site of a very old (1885) record for ponceanus. The Long Key State Recreation area has some short tropical hammock, along with scrub and mangroves, but there were no signs of any ponceanus population on this island.

(4) BIG PINE KEY:

This Key was intensively checked because of the fair amount of natural vegetation still left on the key. We found several rare tropical butterfly species, such as Strymon acis bartrami, here in the pines and palmettos; however, there was no sign of ponceanus or of suitable tropical hardwood habitat for ponceanus.

(5) CUDJOE KEY and SUGARLOAF KEY:

These two keys have low hammock vegetation with reasonably abundant torchwood (U.S. Fish and Wildlife Service, 1982), but we found no mature tall hammock that would match the more northern tropical hardwood hammocks which ponceanus presently occupies. Historically, no Schaus adults or immatures have ever been found here.

(6) KEY WEST:

South of Sugarloaf Key, we found no suitable or even marginal habitat for ponceanus on any key. On Key West, site of an 1885 record with the specimen currently in the Carnegie Museum, no potential habitat for ponceanus remains today.

BISCAYNE NATIONAL PARK

(1) ELLIOTT KEY:

Sixteen survey trips were made to Elliott Key (Figure 3) during 1984, four by the U.F. personnel (May 10, June 4 and 5, September 22) and twelve by Nancy Douglass (May 18, 21, 22, 24, 25; June 11, 12, 20, 26; July 10; August 1, 7). Schaus Swallowtail adults were observed from May 10 through June 5 but not thereafter. No immature stages were found. Heavy rains and flooding after June 5th made the southern portion of the Key inaccessible much of the time to foot travel. These rains may have materially contributed to the short flight season of the adults, as we observed rapid deterioration in wing condition of wild adults even in May under relatively dry conditions.

The total flying population in the 1984 season on Elliott Key was estimated to be thirty adult Schaus Swallowtails, from recaptures of naturally-marked butterflies. The maximum number observed on any one day was seven (May 10th). Only males were found in early May; by June 4-5, the population had declined to about 5-6 relatively old adults, but females now represented half of those seen. All specimens seen were along the Petrel Point Trail in the southern part of the Key; none were encountered on Spite Road itself. More than fifty torchwood trees were checked for larvae and eggs on the short (800 feet) Petrel Point trail, as were forty-five more scattered torchwood and Xanthoxylem along several miles of Spite road. Adult activity was encountered between 9:10 a.m. and 1:10 p.m. Later in the afternoon, no adults were seen. Early in the morning (9:10 a.m.), one female Schaus was observed feeding on the small white flowers of Cheese Shrub (Morinda royoc). Much of the time of adult males was spent in apparent thermoregulating, landing on sunlit branches of torchwood with wings outspread for several minutes at a time. Hindwings frequently had bird beak marks across the scaling or had tears in the wing margins and had missing tails. All adults on Elliott Key were encountered in an area of about 700 linear feet of the Petrel Point trail starting at Spite Road, indicating perhaps site fidelity and little wandering from their home hammock area in this year of extremely low population levels.

(2) OLD RHODES KEY:

The Schaus Swallowtail population on this key (Figure 3) south of Elliott Key was estimated to be a maximum of twenty-four

adults in 1984. The maximum number on any one day was on June 4th when nine ponceanus males and one female were censused. The population was apparently at the peak of its flight season, with a normal age distribution curve of two nearly-freshly-emerged adults, six intermediate-condition adults, and two worn adults (one male, one female). In September, the abundant torchwood here showed old feeding damage but no larvae were present. Liguus tree snails and the tropical Florida Purplewing butterfly (Eunica tatila) were found in numbers in the mature hammock here. The Giant Swallowtail, Papilio cresphontes also occurred here.

(3) TOTTEN KEY:

The Schaus Swallowtail population on this key across Caesar's Creek south of Elliott Key (Figure 3) was estimated to be 12-16 adults in 1984. The peak of the flight season was apparently in May. Two worn males were netted here, plus two other adults observed, during a June 4th visit. Four Giant Swallowtails (Papilio cresphontes) in freshly emerged condition were found among the forty acres of planted wild key lime trees (genus Citus) present near the landing site on this key. Torchwood and Xanthoxylem, wild lime trees were located here in abundance. On the September 22nd visit, a second-instar Papilio larva was found here on Xanthoxylem. Photographs of it were later identified by H. David Baggett as of a second-instar Papilio cresphontes larva. Two adult Papilio cresphontes were seen here on September 22, but no ponceanus adults or immature stages were encountered on that date.

(4) EVERGLADES NATIONAL PARK:

The eastern portion of Everglades National Park, including the Royal Palm visiter center area hammock and local hammocks to the west, were found to be potentially suitable habitat where Papilio aristodemus ponceanus could possibly occur, but no adults or immatures were encountered in May surveys. The Giant Swallowtail Papilio cresphontes was observed in fair numbers here.

DISCUSSION

GENERAL ECOLOGY OF THE SCHAUS SWALLOWTAIL: The adults are remarkably adapted to the tropical hardwood hammock habitat. Of all butterflies known to me, they resemble the tropical nymphalid genus Heliconius most in their highly modified flight behavior, their obvious ability to navigate slowly and carefully around fine obstacles such as branches and spider webs, and their apparently high degree of learning ability ("intelligence") in terms of remembering a territorial flight path and travelling along it on a regular, predictable circuit. They alight frequently on torchwood leaves about 3-4 feet off the ground and "bask" with outspread wings in the sunfleck for a few minutes; they feed on nectar of small white-flowered shrubs; they investigate other ponceanus that enter their territory and fly closely (but slowly) around them for a few moments; etc. They avoid entering open areas unless they are alarmed by someone pursuing them too closely. The frequent tears in the wings suggest a daily toll of damage resulting from maneuvering through the hardwood hammocks, while beak marks and missing tail sections cleanly snipped off suggest rather frequent bird attacks. It is likely that they live only two weeks at most as adults at this rate of wing wear and apparent predation attempts. Yet the extended flight season from the end of April to mid-June suggests that the overwintering (diapausing) pupae do not emerge synchronously, but that adults emerge over at least a 3-4 week period. It is remarkably easy to observe and follow this large and colorful swallowtail through the hammocks or along the trails. I took close-up photographs at distances of six inches

with no great difficulty. The wing-color resemblance in flight to the sympatric, common and distasteful heliconiine butterfly species, the Zebra (Heliconius charitonius), is remarkable also and the similarity in behavior as well as color pattern during flight suggests selection for an incipient mimetic relationship that would protect the adult Schaus Swallowtails against bird attack.

It is clear that suitable torchwood plants for oviposition, with new growth following the late spring and summer rains, occur within the mature hammocks as well as along trails cut through the hammock. In fact, a greater diversity of torchwood trees, from very young to mature canopy-level trees, occurs within the mature hammocks as compared to areas undergoing succession (cf. Rutkowski, 1971). From talking with a number of lepidopterists who have observed the immatures in nature and seen the adults ovipositing, the adult females appear to prefer ovipositing on torchwood or wild lime under the canopy of taller hammock where dappled sunlight comes through, but not intense sunlight or total shade. This habit probably relates to a narrow range of thermoregulatory preference or tolerance on the part of the adult. Time budgets on males and females observed in May and June of 1984 indicated as much as 55% of their time between the peak flight hours of 10:00 a.m. and 1:00 p.m. is spent in basking behavior, sitting with wings outspread on torchwood leaves in a sun fleck.

ELLIOTT KEY POPULATION: The peak of the 1984 flight was in early May. Seven ponceanus males were actually observed in the hand, or at very close range on May 10th, and from capture-recapture data,

the population on that day can be extrapolated to have consisted of approximately 15 males. Assuming a 1:1 sex ratio in eventual emergence (females emerging later than the males), the total population size during May was about 30 individuals in the south-central part of Elliot Key around Petrel Point. Adults were not flying elsewhere on the island at this time, or at any later date (Biscayne National Park naturalists checked these sites weekly, in addition to our U.F. personnel visits). One male and one female were actually observed here in the hand on June 5th under good weather conditions, a record represented two-thirds of the flying population seen at Petrel Point on this visit. None was seen subsequently. Despite diligent searching in May, June, July, August, and September, no immatures were found. The torchwood and key lime were in good shape. Heavy continuous rains at intervals of a week or so in May and June may have limited adult activity this year to lower levels; however, the lack of adults in any numbers on Key Largo where less rain fell suggests another as yet unidentified cause of population decrease.

OLD RHODES KEY POPULATION: The peak of the 1984 flight was in late May and the first week of June. Six males and one female were actually handled and identified, with a series of other males and one unmarked female observed at close range. From these observations, the total population size on this date can be estimated to be approximately 12 males and 2 females, with about 24 butterflies representing the total flying adult population of ponceanus on Old Rhodes Key during May.

TOTTEN KEY POPULATION: The peak of the 1984 flight season was in May. By early June, only worn adults (a total of 6) were seen here. The estimated population size from capture-observation data was about 8-10 males for June 4th, extrapolating to a total population of approximately 16-20 ponceanus for the Key area.

KEY LARGO POPULATION: A little more than ten years ago, ponceanus was passing through one of the largest, if not the largest, population peaks ever recorded in any of the cycles for this species. In 1984, the numbers were extraordinarily low, with one male (?) being observed by the present investigators and no adults (as for as known) being collected that season by any of the Papilio collectors visiting the Keys for that purpose. The attached map (Figure 2) plots the known distribution of specimens collected in the 1970's and the location of the 1984 specimen observed at the boundary of Hammocks 13 and 14 one-half mile south of the Carysfort Yacht Club road turnoff. These data were gathered from published records on museum specimens with full data, and from unpublished records taken by collectors who wished to remain anonymous but shared information for the purposes of this status survey. It should be noted that most records (Hammock Nos. L(1)6, 9, 10, 11, 13, 14) are concentrated in the remaining native hammock areas of northern Key Largo, and that the southernmost record known since 1970 is just north of Gulfstream Shores (Hammock No. L(2)5).

From all accounts of experienced collectors of Schaus Swallowtails, the butterfly has always occurred in numbers east of Highway 905 and particularly along trails or inside native

hammocks (with a relatively open understory composed of torchwood, wild lime, poisonwood, and young hardwood saplings) where dappled sunlight penetrates at mid-day. While it flies slowly along the edges of hammocks on occasion, it very rarely flies into open areas. On the other hand, its congener, the Giant Swallowtail Papilio cresphontes is usually flying relatively rapidly across open areas and visiting flowers along roadsides or in fields; female cresphontes frequent the hammocks more than males.

CONCLUSIONS AND RECOMMENDATIONS

The populations on the Keys in Biscayne National Park, while very low for continued species survival if considered individually, form a viable nucleus in the aggregate for the Schaus Swallowtail's existance and for captive-propagation stock. The chief danger of having such a geographially-limited nucleus arrises from natural disasters, such as hurricanes, fires, or winter freezes, wiping out the sole remaining viable stocks. Because of their size (larger than the Key Largo population), they are the most suitable populations to continue more intensive studies in the future on the species' population ecology, especially population size, life span as adults, predation and parasitism, and amount of movement of adults (especially between keys.or across distances representing such degrees of isolation). These populations are rarely seen by human visitors because few can brave the hordes of mosquitoes and flooded ground conditions during the time of the usual Schaus flight period. Thus few people can enjoy their beauty, whereas on keys from Key Largo south, thousands of visitors a month could potentially see these attractive butterflies during past peak years. It seems important, therefore, to foster the butterfly's continued existance.

On the basis of available torchwood hast plants and historical records for Schaus Swallowtail adutls, the optimum hammock characteristics for the butterfly on Key Largo are found in:

Hammock L(1)6

Hammock L(1)11

Hammock L(1)9

Hammock L(1)10 B

Hammock L(1)13-14

Hammock L(2)1

as depicted in Figure 2 (sections L-1 and L-2 of Northern Key Largo) of the Recovery Plan of the U.S. Fish & Wildlife Service (1982, p. 55). As far as the preservation of the butterfly is concerned, then, it is important to protect existing habitat on Key Largo by expanding Crocodile Lakes National Wildlife Refuge to include all of hammocks L(1)6, 9, 10 B, 11, 13, and 14 on the east side of Highway 905. The narrow strip of hammock L(2) 1 on the west side of Highway 905 has abundant torchwood in places, but by comparison with the other hammocks, may not be broad enough to support a viable population of Schaus Swallowtails by itself without association with hammocks east of Highway 905 (cf. recommendations in the Recovery Plan, criterion 1131 on page 23 and page 46, U.S. Fish & Wildlife Service, 1982, where Hammocks 6 and 9 were omitted on page 23 but included on page 46 in lists of essential habitat areas.)

It would also be feasible to reintroduce the Schaus Swallowtail into northern Key Largo hammocks from the larger populations in Biscayne National Park. In meeting this Recovery plan recommendation (step 13, p. 31, USF&WS, 1982) to reestablish ponceanus colonies in appropriate areas within its historic range, sites containing historically suitable habitat will have to be secured (steps 1311 and 1312, p. 31) and a decision will have to

be made regarding initiation of captive propagation versus transfers of wild adult individuals. From past experience with breeding rare butterflies, it would seem safer and more practical to remove a limited number (10-12) eggs or young larvae from the wild on Elliott or Old Rhodes Keys and use these as the basis for a breeding stock, than to remove an equivalent number of adults from the wild and transfer them between islands. A single female swallowtail is capable of laying over 100 eggs, and the close-to-95% loss in nature between egg and adult stages (USF&WS, 1982) is due to many selective factors such as parasitism and predation which can be excluded in the laboratory. Wild adult transfers have not been successful with other butterfly species as regards new colony establishment. However, transfers of eggs and larvae from montane Wyoming populations of the checkerspot nymphalid butterfly Euphydryas gellettii south to locations in the central Colorado mountains have resulted in the firm establishment of at least one Colorado population (Holdren and Ehrlich, 1981), and transfers of pupae have been used in south Florida to establish many new populations of the Florida Atala lycaenid butterfly, Eumaeus atala, in the past several years (R. Boender and P. Henry, unpublished). Adult transfers in the past have not successfully established the Atala butterfly in the same Everglades National Park areas (Rawson, 1961).

The problem with initiating reestablishment of the Schaus Swallowtail in the northern Key Largo area is that extensive aerial spraying of mosquito insecticides on the keys during the past decade may be responsible for the precipitous decline in numbers of the butterfly there. In this respect, then, it is

recommended that: (1) captive propagation of ponceanus be initiated with the aim of reintroduction into areas that are not being sprayed, or that spraying by the Monroe County Mosquito Control District be suspended in the areas where the butterfly is presently found or is to be released; (2) pesticide testing experiments be initiated with the parental subspecies of the Schaus Swallowtail, Papilio aristodemus aristodemus, collected and bred from material taken in the Dominican Republic on the island of Hispaniola, and assessment of the relative toxicity to the butterfly of each component of the complex spray mixture be undertaken.

Finally and most clearly, the tropical hardwood hammock in appropriate areas and quantities on Key Largo will need to be preserved in order to attain any of these objectives, and to insure the continued existance of the endangered Schaus Swallowtail outside its present reduced range (1984) in Biscayne National Park and one area on Key Largo. A substantial side benefit of this course would be to have this distinctive large butterfly in areas readily available to public observation during its flight season, an example of an endangered species brought back from the edge of extinction by sound environmental policies.

REFERENCES

Brown, L. N. 1973. Populations of Papilio andraemon bonhotei Sharpe and Papilio aristodemus ponceanus Schaus (Papilionidae) in Biscayne National Monument, Florida. J. Lepid. Soc. 27 (2): 136-140.

Brown, L. N. 1974. Haven for rare butterflies. National Parks and Conserv. Mag., July 1974: 10-13.

Covell, C. V. Jr. 1976. The Schaus swallowtail: a threatened subspecies? Insect World Digest 3 (5): 21-26.

Covell, C. V. Jr. 1977. Project Ponceanus and the status of the Schaus swallowtail (Papilio aristodemus ponceanus) in the Florida Keys. Atala 5 (1): 4-6.

Covell, C. V. Jr., and G. W. Rawson. 1973. Project ponceanus: A report on first efforts to survey and preserve the Schaus swallowtail (Papilionidae) in southern Florida. J. Lepid. Soc. 27: 206-210.

Covell, C. J., Jr. 1982. The Florida Trip, May 19-21, 1982. Kentucky Lepidopterist, 8 (2): 3.

Grimshawe, F. M. 1940. Place of sorrow: the world's rarest butterfly and Matecumbe Key. Nature Mag. 33: 565-567, 611.

Henderson, W. F. 1945a. Papilio aristodemus ponceana Schaus (Lepidoptera: Papilionidae). Entomological News 56: 29-32.

Henderson, W. F. 1945b. Additional notes on Papilio aristodemus ponceana Schaus (Lepidoptera: Papilionidae). Entomological News 56: 187-188.

Holdren, Cheryl E., and Paul R. Ehrlich. 1981. Long range dispersal in checkerspot butterflies: transplant experiments with Euphydryas gillettii. Oecologia(Berl.) 9, 50: 125-129.

Little, E. L. 1978. Atlas of United States Trees. Volume 5: Florida. U.S.D.A.

Miller, L. D. 1975. Threatened status for two butterflies? Field Museum Nat. Hist. Bull. 1975: 15-18, 22.

Rawson, George W. 1961. The recent rediscovery of Eumaeus atala (Lycaenidae) in southern Florida. J. Lepid. Soc. 15 (4): 237-244.

Rutkowski, F. 1971. Observations on Papilio aristodemus ponceanus (Papilionidae). J. Lepid. Soc. 25: 126-136.

Schaus, W. 1911. A new Papilio from Florida, and one from Mexico (Lepid.). Entomol. News 22: 438-439.

U.S. Fish and Wildlife Service. 1982. Schaus Swallowtail Butterfly Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 57 pp.

MAP FIGURES

Figure 1. General map of south Florida mainland, principal keys in Biscayne National Park, and the Florida Keys, including the historic range of the Schaus Swallowtail (*Papilio aristodemus ponceanus*) from Miami to Lower Matecumbe Key and Key West.

Figure 2. Tropical hardwood hammocks (numbered after U.S. Fish and Wildlife Service, 1982, Figure 3 maps) and other habitat types on northern Key Largo, Monroe County, Florida. Specific locality records of museum and private-collection specimens of Schaus Swallowtails, where more detailed information than solely "Key Largo" labels was available, are shown by black stars. The 1984 record is shown by a white star.

Figure 3. Map of principal keys in Biscayne National Park, Dade County, Florida. Locations of 1984 populations of the Schaus Swallowtail on Elliot, Old Rhodes, and Totten Keys are shown by white stars.

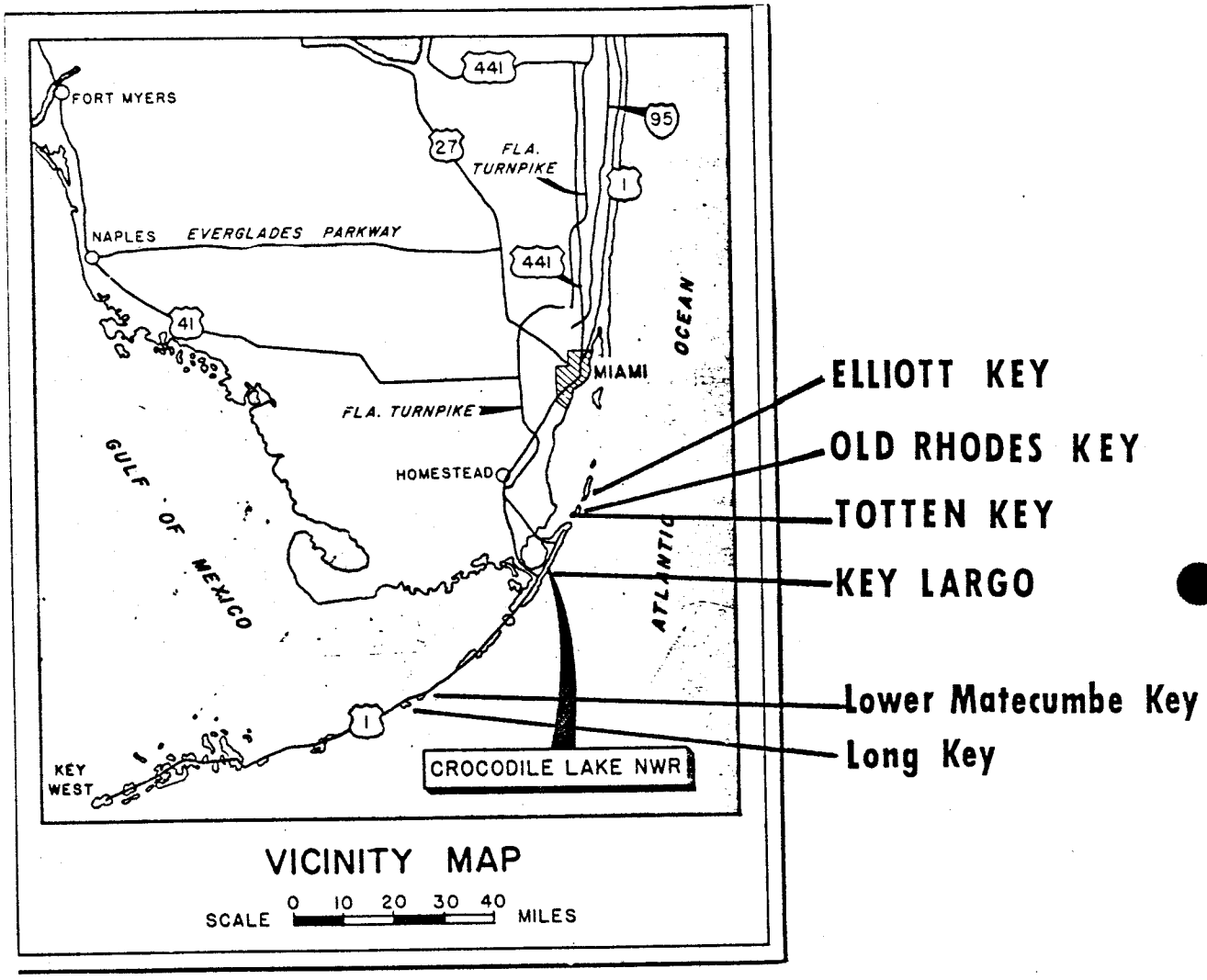

FORT MYERS
441
95
27
FLA.
TURNPIKE
1
NAPLES
EVERGLADES PARKWAY
441
41
MIAMI
OCEAN
FLA. TURNPIKE
HOMESTEAD
GULF OF MEXICO
ATLANTIC
1
KEY
WEST
CROCODILE LAKE NWR
VICINITY MAP
SCALE 0 10 20 30 40 MILES
ELLIOTT KEY
OLD RHODES KEY
TOTTEN KEY
KEY LARGO
Lower Matecumbe Key
Long Key

Figure 1

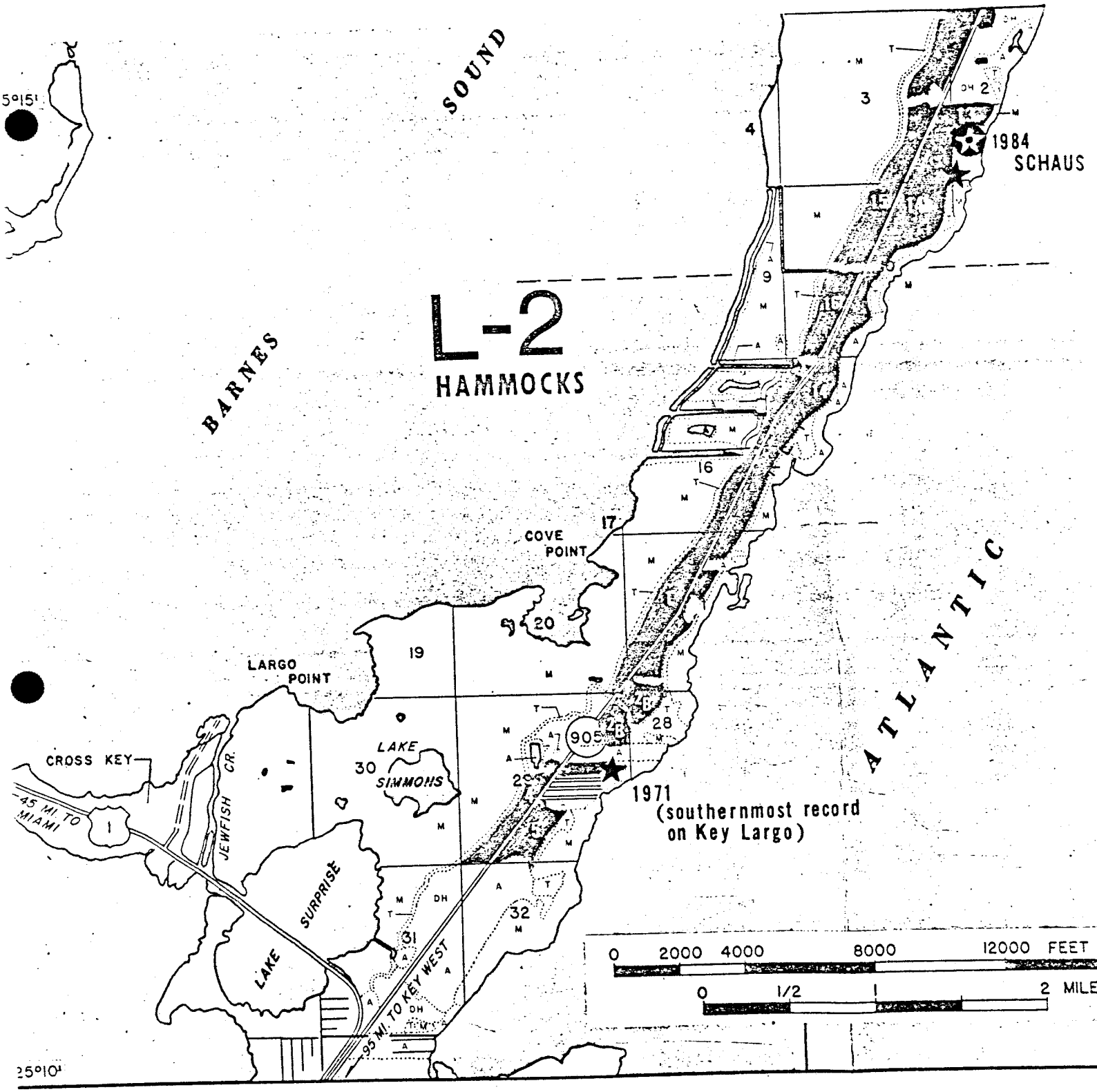


Figure 2a. NORTHERN KEY LARGO

MONROE COUNTY, FLORIDA

LEGEND

A	ALTERED LAND
DH	DISTURBED HAMMOCK
H	HAMMOCK
M	MANGROVE
T	TRANSITION ZONE

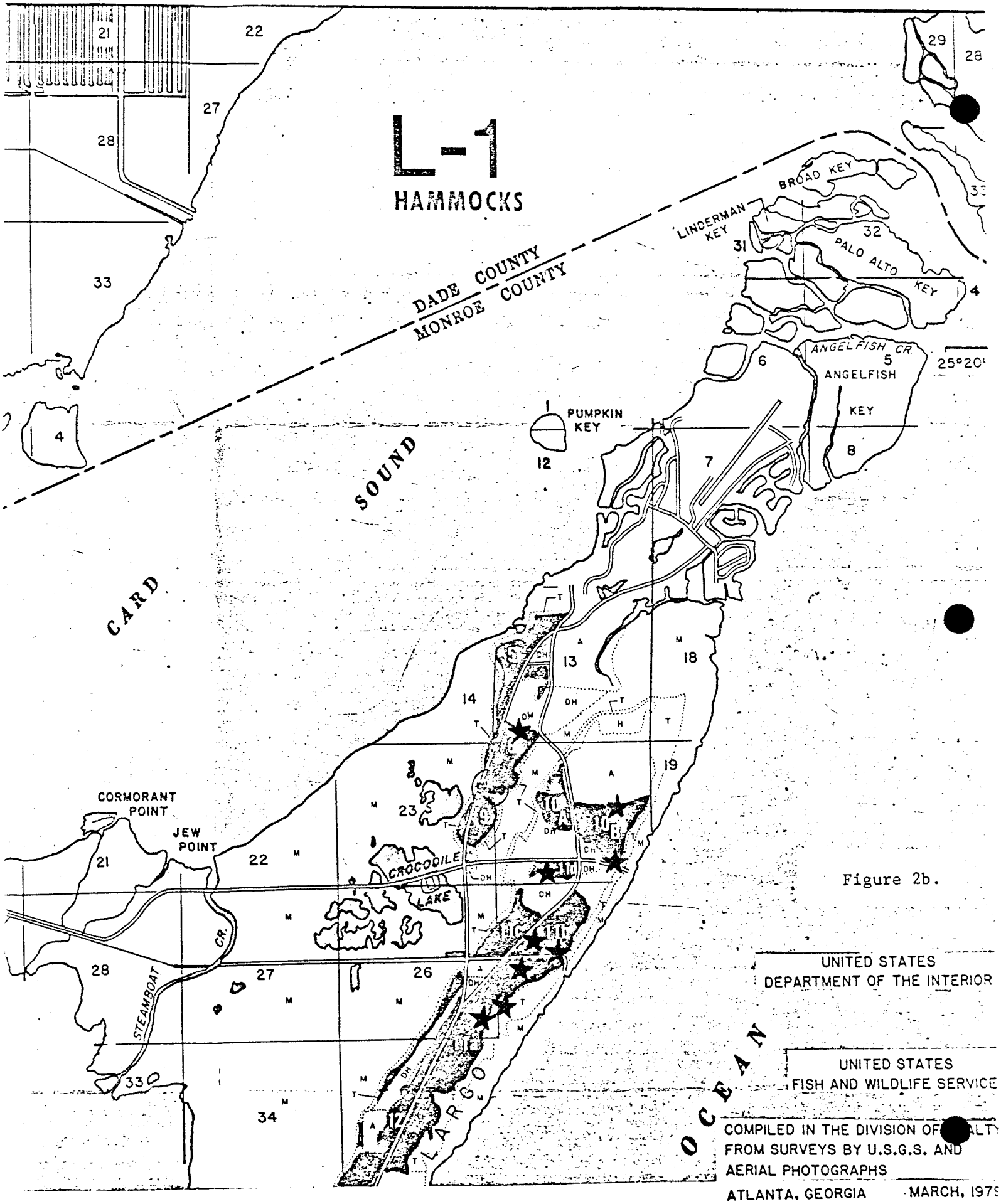

L-1
HAMMOCKS
DADE COUNTY
MONROE COUNTY
BROAD KEY
LINDERMAN KEY
PALO ALTO KEY
ANGELFISH CR
ANGELFISH KEY
PUMPKIN KEY
SOUND
CARD
CORMORANT POINT
JEW POINT
CROCODILE LAKE
CR.
STEAMBOAT
LARGO
OCEAN
UNITED STATES
DEPARTMENT OF THE INTERIOR
UNITED STATES
FISH AND WILDLIFE SERVICE
COMPILED IN THE DIVISION OF
FROM SURVEYS BY U.S.G.S. AND
AERIAL PHOTOGRAPHS
ATLANTA, GEORGIA
MARCH, 197

Figure 2b.

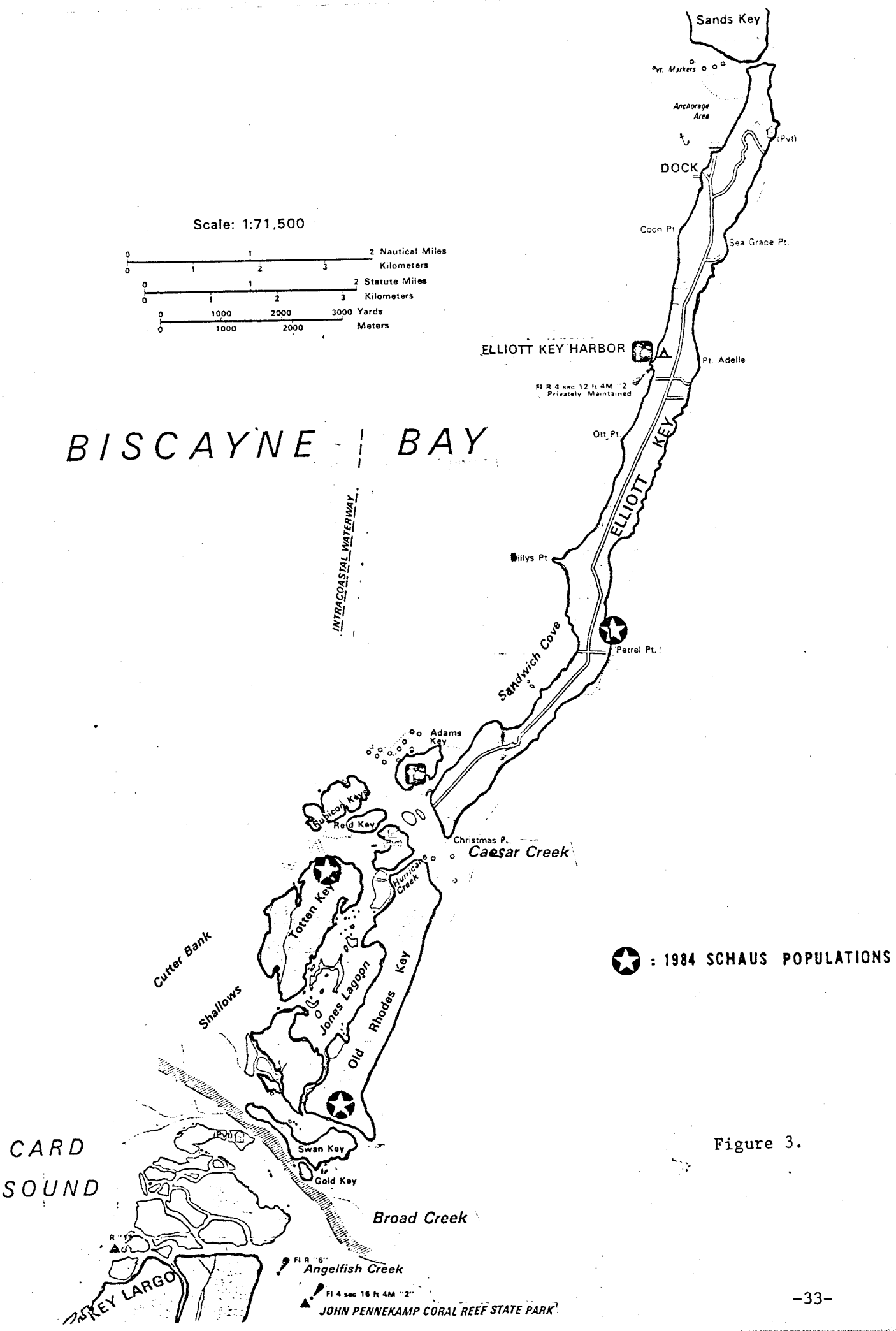

Sands Key
Pvt. Markers
Anchorage Area
(Pvt)
DOCK
Scale: 1:71,500
0 1 2 Nautical Miles
0 1 2 3 Kilometers
0 1 2 Statute Miles
0 1 2 3 Kilometers
0 1000 2000 3000 Yards
0 1000 2000 Meters
Coon Pt
Sea Grape Pt.
ELLIOTT KEY HARBOR
Pt. Adelie
Fl R 4 sec 12 ft 4M "2"
Privately Maintained
Ott Pt.
BISCAYNE BAY
INTRACOASTAL WATERWAY
ELLIOTT KEY
Billys Pt.
Petrel Pt.
Sandwich Cove
Adams Key
Boca Chica Key
Red Key
Christmas P.
Caesar Creek
Hurricane Creek
Totten Key
Cutter Bank
Shallows
Jones Lagoon
Old Rhodes Key
: 1984 SCHAUS POPULATIONS
CARD SOUND
Swan Key
Gold Key
Broad Creek
Fl R "6"
Angelfish Creek
KEY LARGO
Fl 4 sec 16 ft 4M "2"
JOHN PENNEKAMP CORAL REEF STATE PARK

Figure 3.

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GAINESVILLE, 32611

DIVISION OF LEPIDOPTERA RESEARCH
OFFICE OF THE DIRECTOR

DEPARTMENT OF ZOOLOGY
223 BARTRAM HALL
904 392-1107

QUARTERLY PROGRESS REPORT
1985-86 FY

PROJECT NUMBER: GFC-84-028

PROJECT TITLE: Status Survey and Habitat Requirements of Florida's Endemic Schaus Swallowtail Butterfly

PROJECT DIRECTOR: Thomas C. Emmel
Professor of Zoology
Director, Division of Lepidoptera Research
University of Florida
Gainesville, Florida 32611

DATES COVERED BY REPORT: July 1 to September 30, 1985

DATE REPORT WAS SUBMITTED: October 15, 1985

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I. INTRODUCTION

The purpose of this project is to determine the 1985 and 1986 status of the Schaus Swallowtail butterfly, Papilio (Heraclides) aristodemus ponceanus Schaus, a large and colorful member of south Florida's endemic insect fauna that is currently on the Endangered Species list. In 1984, the total known population size was approximately 70 or fewer adult butterflies. It was on the verge of extinction on northern Key Largo (one adult) that year, and in precarious status on three keys in Biscayne National Park, the sole colonies found during an intensive 1984 survey throughout the Forida Keys. The project objectives in 1985 (and 1986) are to carry out intensive field surveys during the normal flight season (late April to mid June) to determine population sizes, assess the key characteristics of their prefered hardwood hammock habitats, and to determine major parameters affecting the population dynamics of the

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butterfly. This information should assist in effective management planning and actions to improve the chances for survival of this large tropical species in our Florida fauna.

II. PROGRESS:

As reported in our previous Annual Report of June 14, 1985, intensive surveys were carried out from the first week of May to mid June 1985 on northern Key Largo and the keys in Biscayne National Park. Transects were established across all hammock area on north Key Largo and along the entire length of Elliott Key. Detailed mappings of hammocks, locations of first sightings of adults, presence of eggs and each of the five larval instars, the locations of torchwood and wild lime larval hosts, the locations of adult feeding plants, and hammock disturbance, were recorded. All netted adults were marked with individual numbers in permanent ink on the underside of the right forewing. Their precise location was recorded in relation to the specific transect markers previously mapped. The sex, wing condition ("age"), bird beak marks, or other features of interest were recorded, and the specimen was released unharmed in the same location. The time of capture was recorded. Subsequent recaptures (including same-day recaptures) were treated similarly. Condition of host plants (larval) and feeding plants (adults) was recorded at all sites.

During the most intensive period of capture-recapture work along a gravel trail ("Spite Highway") running through the hammock for four miles on Elliott Key, three workers observed and marked 191 adult ponceanus in eight days (May 28-31 and June 3-6, 1985); 28 of these butterflies were subsequently recaptured one or more times during the study period. Capture records were not distributed equally along the trasnect; the

majority of captures were recorded between markers 12 and 15, near Petrel Point Trail. This area was particularly favorable habitat, with dense hammock and an abundance of the prefered larval foodplant, Torchwood (Amyris elemifera). Males were captured significantly more frequently than females (male:female sex ratio = 2.5:1; chi-square = 36.4, $p < .0001$). While this could have been due to male patrolling behavior, we did not find a greater number of females in the deep hammock, so the population may have a male-biased sex ratio. The male recapture rate was 17.5%; the female recapture rate was lower (7.4%). However, this difference is not statistically significant (chi-square = 3.14; $.05 < p < .10$).

Several ponceanus individuals in this continuous eight-day study were recaptured as long as eight days after release, and many had moved a substantial distance from their original capture point. The greatest recorded movement was approximately 2.9 miles (over 8 days). Another butterfly (# 38) was recaptured over 2 miles from its original point of capture after only two days. It is clear from these results that the butterfly is capable of crossing the short distances between the keys in Biscayne National Park and northern Key Largo, as well as keys to the south of Key Largo if that resident population increases and can move into southern Key Largo. A detailed analysis of the capture-recapture data for movements and population estimates is still in progress.

In terms of diurnal activity patterns, adult ponceanus were sighted from 8:35 a.m. to 7:15 p.m., a much longer activity period than has been previously reported. Both males and females were captured before 9:00 a.m. Males were sighted on 13 occasions after 4:00 p.m., flying at high speeds in open grassy areas outside the hammock. No confirmed female individuals were sighted outside the hammock habitat

after 3:30 p.m. Diurnal activity pattern differences between the sexes appear to be limited. Females were more abundant in the middle of the day, especially between 11:30 a.m. and 2:00 p.m. Males were more frequent than females at all times, but particularly in the morning (i.e., 9:00 a.m. to 12 noon).

Detailed descriptions of courtship behavior will be presented in the final report, as well as details of nectaring and oviposition behavior. A key discovery to take special note of, however, is that females appear to be extremely selective in searching for oviposition sites. Relative to other papilionids, ponceanus females spend a very long time examining the foodplant before ovipositing. Based on egg collection records, only the youngest torchwood leaves are preferred by an ovipositing female. Based on our later summer rearing of ponceanus in captivity, only the youngest torchwood leaves were chemically acceptable to the larvae and without fresh growth at the ends of torchwood branches, the larva would basically feed just enough to stay alive and not grow. Our analysis of rainfall patterns and emergence patterns suggests that the general emergence and biologically important activities of the adults are closely tied to the initiation of the rainy season in south Florida because of this requirement for new torchwood growth (presumably lacking protective chemicals developed in older leaves, a point still to be tested).

In terms of population estimates, the mark-recapture program on Elliott Key gave sufficient data to make reasonable statements about population size and density along the transect and for the island. As mentioned above, the population data will be analyzed further this winter; however, several summary comments can be made now. The life span is surprising short for a papilionid: approximately six days, on the average.

The butterflies also are capable of moving considerable distances from the transect, including retreat into deeper hammock where capture is not as likely, and these factors are believe to result in the low observed recapture rates. (Post-capture mortality due to the handling procedure is believed to be non-existent, since behavior was normal after release in all cases and fresh individuals were followed as long as eight days after marking.) A number of statistical analyses were utilized in an attempt to obtain an accurate total population estimate. Due to various procedural differences, including implicit assumptions, the methods yield different numbers. The Manley-Parr technique provided an estimate for only one day, May 31, for example, where the estimated flying population was 191 adults. The Jolly Seiber method allowed daily population estimates, which ranged from 96 to 1217 (!) butterflies on Elliott Key. Two modifications of Lincoln Index techniques yielded the most satisfactory estimates (751 flying adults between May 28 and 31, and 690 flying adults between June 3 and 6). No method has provided entirely satisfactory results, but we believe the total 1985 population of ponceanus on Elliott Key was between 700 and 850 adults. This is up dramatically from the 1984 level of less than 30 adult butterflies.

Full data and results on these points and on life-history parameters will be presented later this year. We are developing complete illustrations for identification of all Schaus life history stages contrasted with its congener, the Giant Swallowtail (Papilio cresphontes), that is sometimes found on the same foodplants. These will be useful to south Florida law enforcement personnel in addition to biologists. Our captive propagation project (pilot program from ten eggs) has resulted in two diapausing pupae, one appearing to be male and the other a female, which are being held until torchwood under cultivation in our greenhouses has put forth fresh

growth. All other aspects of the program continue to be on schedule as outlined in the original STUDY PROPOSAL and ADDENDUM, and the ANNUAL REPORT of 14 June 1985.

III. PLANS

During the next quarter, as originally outlined in the STUDY PROPOSAL and ADDENDUM, we will continue the analysis of the population data and mapping projects, including measurement of habitat areas from aerial photographs and ground-survey data, The pupae will be brought out of diapause if hostplants are suitable during this coming quarter, and hand-pairing attempted. Plants brought up from south Florida native-plant nurseries during our last field trip (September 27-29, 1985) to Key Largo, Biscayne National Park, and the Homestead area should meet this need. Life-history comparisons and a short paper on the 1985 population measurements compared to 1984 will be written up. Continued interviews and solicitations of information from lepidopterists who have experience with this species will be conducted. Planning will start for the next flight season, May-June 1986, after examination and review of the complete data set for 1985.

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DIVISION OF LEPIDOPTERA RESEARCH
OFFICE OF THE DIRECTOR

DEPARTMENT OF ZOOLOGY
223 BARTRAM HALL
904 392-1107

January 10, 1986

NONGAME WILDLIFE RESEARCH GRANT
QUARTERLY PROGRESS REPORT
1985-86 FY

PROJECT NUMBER: GFC-84-028

PROJECT TITLE: Status Survey and Habitat Requirements of Florida's Endemic Schaus Swallowtail Butterfly

PROJECT DIRECTOR: Dr. Thomas C. Emmel
Professor of Zoology and
Director, Division of Lepidoptera Research
University of Florida
Gainesville, Florida 32611

DATES COVERED BY REPORT: October 1 to December 31, 1985

DATE REPORT WAS SUBMITTED: January 10, 1986

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I. INTRODUCTION

The purpose of this project is to determine the population status of the Schaus Swallowtail butterfly, Papilio (Heraclides) aristodemus ponceanus Schaus, a large and colorful Endangered Species in south Florida's endemic insect fauna. The total known population was reduced to less than 70 adults by 1984, and the butterfly was on the edge of extinction on northern Key Largo (one adult) that year while persisting in three isolated key populations of 16-30 individuals each inside Biscayne National Park. The occurrence of the butterfly on Key Largo in particular was of great interest because of plans to save a portion of the remaining tropical hardwood hammock habitat there from development. The project objectives during 1985 and 1986 were stated in the original STUDY PROPOSAL to include

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intensive field surveys during the normal late-April to mid-June 1985 and 1986 flight seasons to determine current distribution and population sizes, assessment of the key characteristics of the species' prefered hardwood hammock habitats, and determination of major parameters affecting the population dynamics of the butterfly. Added to this work was authorization to conduct a limited pilot captive-propagation attempt by removal of 10 wild-collected eggs and rearing of the species at Gainesville. The information gathered from these Nongame Wildlife Program-supported studies, plus a study of the effects of pesticides on the survival of the Schaus Swallowtail butterfly which was subsequently funded by the Elizabeth Ordway Dunn Foundation of Florida and Charles L. Siemon of Chicago, should assist in effective management planning and state/federal actions to improve the chances for survival of this large tropical species in our Florida fauna .

II. PROGRESS

As stated in the original STUDY PROPOSAL and ADDENDUM, this quarter involved data analysis at the University of Florida and continued gathering of weather information, historical information , etc., for the prospective identification of major parameters affecting the population dynamics of the butterfly. An artist assistant prepared all of the needed drawings of the lateral and dorsal aspects of each of the five larval instars of Papilio aristodemus ponceanus and Papilio cresphontes, a species with which ponceanus can be confused in the field since they use the same hosts on occasion. Photographic illustrations were prepared of the pupae and adults of both species, and the comparative life history of ponceanus was described.

Maps were drawn for future publication and the final report on this project of the capture-recapture results, individual movements, and a portion of the hammock distribution relating to Schaus concentrations.

In the captive propagation project, approximately 30 Torchwood trees and 40 Wild Lime (Zanthoxylem fagara) were established in our older greenhouse space, and construction was started on a new greenhouse which would be devoted completely to the Schaus project. The two diapausing pupae resulting from the captive rearing of five Schaus larvae (derived from five fertile Schaus eggs and one cresphontes egg (plus 4 infertile eggs collected on Elliott Key) continued to be held in a constant-temperature room in Bartram Hall at Gainesville, and a temperature-rainfall (simulated) regime was started in December to prepare them for emergence.

In the pesticide research project, arrangements were completed with Mr. Ron Boender of Fort Lauderdale to undertake the rearing of up to 3,000 Papilio cresphontes larvae, to be shipped at a rate of 200 or more a week starting at the end of March to us at Gainesville, for the initial complex screening procedure needed to assay the effects of the various pesticides being sprayed by Monroe County in the Keys. Samples of the pesticides were obtained from Mrs. Lois Ryan and Mr. Henry Hurtekant, Supervisor, at the Monroe County Mosquito Control District office on Stock Island on Monday, October 21, 1985. Details were secured on the history of spraying for mosquito control in the northern and central keys, and the exact schedules, amounts, mixtures, etc., utilized in the past and present. This promises to be an exceptionally interesting story in relation to the Schaus Swallowtail's history, and Key Largo wildlife in general perhaps. We have also ordered and obtained the equipment necessary to carry out this project, and made an initial field trip to the Dominican Republic from December 26, 1985 to January 5, 1986, to secure Papilio aristodemus aristodemus females

All aspects of the research program continue to be on schedule as outlined in the original STUDY PROPOSAL and ADDENDUM, and the ANNUAL REPORT of 14 June 1985 as well as the QUARTERLY REPORT of 15 October 1985.

III. PLANS

During the coming quarter, as originally outlined in the STUDY PROPOSAL and ADDENDUM, we will continue the analysis of the population data from the summer of 1985 and the various mapping projects. New aerial photographs will be ordered after suggestions from several workers as to more satisfactory LANDSAT photographs. The pupae will be brought out of diapause when hostplants are ready, and hand-pairing attempted. Two papers will be completed on the Schaus life history and on the 1984-85 population recovery. Continued interviews and solicitations of data on the Schaus populations historically will be obtained from other lepidopterists in Florida and across the U.S. Detailed planning and correspondence for the 1986 flight season arrangements will be done.

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DIVISION OF LEPIDOPTERA RESEARCH
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DEPARTMENT OF ZOOLOGY
223 BARTRAM HALL
904 392-1107

April 8, 1986

NONGAME WILDLIFE RESEARCH GRANT
QUARTERLY PROGRESS REPORT
1985-86 FY

PROJECT NUMBER: GFC-84-028

PROJECT TITLE: Status Survey and Habitat Requirements of Florida's Endemic Schaus Swallowtail Butterfly

PROJECT DIRECTOR: Dr. Thomas C. Emmel
Professor of Zoology and
Director, Division of Lepidoptera Research
University of Florida
Gainesville, Florida 32611

DATES COVERED BY REPORT: January 1 to March 31, 1986

DATE REPORT WAS SUBMITTED: April 8, 1986

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I. INTRODUCTION

The purpose of this project is to determine the 1985 and 1986 population status of the Schaus Swallowtail butterfly, Papilio (Heraclides) aristodemus Schaus. a large and colorful member of south Florida's endemic insect fauna that is currently on the Endangered Species list. After an apparently steady decline since 1973, the total known population size was reduced to 70 adults by 1984, and the butterfly was on the verge of extinction on northern Key Largo (one adult) that year while persisting in three isolated Key populations of 16-30 individuals each inside Biscayne National Park. The occurence of the butterfly on Key Largo in particular was of great interest because of State and Federal plans to save a portion of the remaining tropical hardwood hammock habitat there from development.

EQUAL EMPLOYMENT OPPORTUNITY/AFFIRMATIVE ACTION EMPLOYER

The original STUDY PROPOSAL included the project objectives during 1985 and again in 1986 to conduct intensive field surveys during the normal late-April to mid-June flight season in order to determine current distribution and population sizes, to assess the key characteristics of the species' prefered hardwood hammock habitat and hostplants, and determination of major parameters (including historical climatic changes and events) affecting the population dyanamics of the butterfly. Added to this work by the State and by federal permission was authorization to conduct a limited pilot captive-propagation attempt by removal of 10 wild-collected eggs and rearing of the species at Gainesville. The information gathered from these Nongame Wildlife Program-supported studies, plus a study of the effects of pesticides on the survival of the Schaus Swallowtail butterfly which was subsequently funded by the Elizabeth Ordway Dunn Foundation of Florida and Charles L. Siemon on Chicago, should assist in effective management planning and state/federal actions to improve the chances for survival of this large attractive tropical butterfly in our Florida fauna.

II. PROGRESS

As stated in the original STUDY PROPOSAL and ADDENDUM, this third annual quarter primarily involved data analysis at the University of Florida and the continued gathering of weather information on climatic changes since 1915, seasonal changes in weather that might cue emergence of the Schaus Swallowtail overwintering pupae, historical information on the abundance of the butterfly species, etc., for the prospective identification of major parameters affecting the population dynamics of the species. The life-history paper comparing the life-history stages of

the Schaus Swallowtail (egg, five larval stages, pupa, and adult) with those of its close sympatric congener, the Giant Swallowtail (Papilio cresphontes), has been almost completed, as have single-sheet plates intended for identification and handout use by FG&FWFC enforcement personnel and interested naturalists. Additional aerial photographs (infrared color 36" x 36") have been ordered from the NHAP National High Altitude Photography Program and the U.S. Geological Survey, in order to more precisely map the existing hammock and compare habitat quality in Schaus-occuped vs. unoccupied hammock remnants on Key Largo and Elliott/ Old Rhodes/Totten Keys.

In the captive propagation project, the most notable event was the emergence of the first Schaus Swallowtail from a diapausing pupa on March 15, 1986. Emergence was induced by a combination of lowered temperatures and a dry-wet rainfall pattern in the constant-temperature room. Unfortunately, this specimen (a male with normal body and genitalia structures) had deformed wings and was unable to fly, dying within 24 hours of emergence. The second pupa resulting from last year's rearing program has failed to emerge to date and may be dead of natural causes from early in the pupal period (the proboscis case along the edges of the wing pad cases was not normally formed at pupation). Approximately 30 Torchwood trees and 40 Wild Lime (Zanthoxylem fagara) trees from native plant nurseries in the south Miami area are established and growing well in our greenhouses, and a decision will be made soon here as to whether to request permission to attempt additional rearing of ponceanus. Regardless of that option, these hosts will be useful with one or more other subspecies of Papilio aristodemus (from the Dominican Republic, Grand Cayman, or the Bahamas) that will be brought in as part of our pesticide research with the species.

In the pesticide research project, we started to receive shipments in March 1986 of Papilio cresphontes larvae from MetaScience, Inc., of Fort

Lauderdale, who is rearing these larvae under contract as part of the Dunn Foundation-supported study of the effects of Monroe County spraying programs on the Schaus Swallowtail. We have begun the complex assay experiments to determine the effects of the various pesticides being applied on Key Largo by the Monroe County Mosquito Control District, and these studies are continuing on an almost daily basis as shipments are received. Samples of the pesticides (with one exception still be to obtained) were obtained directly from Mrs. Lois Ryan and Mr. Henry Hurtekant, Supervisor, at the Monroe County Mosquito Control District headquarters on Stock Island. Data on spraying schedules, amounts, etc., were also obtained.

The results to date indicate a possible MAJOR ROLE of pesticide spraying in the decline of the Schaus Swallowtail. Because of the obvious controversy this news will generate, we would prefer to gather the full range of data points before submitting a complete report to the Dunn Foundation and the Nongame Wildlife Program. At the moment, we can summarize the results by saying that Chevron Chemical Company (ORTHO) recommends the application of a 5% (v/v) solution of Dibrom for mosquito control. Monroe Country uses a 4% (v/v) solution with Ortho additive solvent, No. 2 diesel fuel and fog oil, which is applied at a rate of 16 oz per acre of the mixed 4% solution (=0.64-0.80 oz pure Dibrom per acre). Our preliminary experiments show that the cresphontes swallowtail larvae are not affected by either the additive solvent, the diesel fuel, or the fog oil, but the 4% Dibrom solution is 100% lethal to third-instar larvae at the application dosage rate expected under field conditions. In fact, the LD50 rate (the point at which 50% of the treated larvae will survive) seems to be one-eighth that of the field application of Dibrom; in other words, at 0.25-0.50% Dibrom solutions. We must verify and refine these figures before any public mention is made of this discovery with regard to Dibrom, and we also want to complete the testing program with the other pesticides being used before

any public mention. We have not communicated this to Monroe County or Chevron yet because the tests are still highly preliminary in terms of total larvae tested to date (200 as of this week).

These data do concern us as regards a causal factor in the decline of the Schaus Swallowtail and a great many other butterfly species on Key Largo, as noted annecdotally over the past 15 years by lepidopterists. We shall attempt to show the historical relationship of spraying schedules, etc., in a later report. We also plan to import Schaus Swallowtail larvae (i.e., of related subspecies) from the Dominican Republic (P. aristodemus aristodemus), Grand Cayman Island (P. aristodemus temenes), and/or Great Inagua Island in the Bahamas (P. aristodemus bjorndalae) in June or later this summer and run the final series of tests with pesticides on aristodemus larvae of one of these closely related taxa. At the beginning of the present quarter, T. C. Emmel and J. L. Nation located several colonies in northern Dominican Republic (January 1-5, 1986) where fresh females and immatures can be obtained later this year, and we have detailed information from Karen Bjorndal, Lee D. Miller and Mark Simon as to locations on Great Inagua. A biology teacher on Grand Cayman, Tony Huseman, and a lepidopterist acquaintance of T. C. Emmel, Orrin Merran, have been in contact with us this week about collecting live Schaus Swallowtails (temenes) there later this spring.

Arangements have been made with Biscayne National Park to commence 1986 field work on Elliott Key the first two weeks of May, and we will be working on Key Largo and surveying the rest of the Keys from mid May to July. All aspects of the research program continue to be on schedule as outlined in the original STUDY PROPOSAL and ADDENDUM, and the ANNUAL REPORT of 14 June 1985, the QUARTERLY REPORT of 15 October 1985, and the QUARTERLY REPORT of 10 January 1986.

III. PLANS

During the coming fourth quarter of 1985-86 FY, as originally outlined in the STUDY PROPOSAL and ADDENDUM, we will repeat the field work protocol followed in 1985 with the modification that four people will work an intensive ten-day (continuous) capture-recapture program on Elliott Key during the first two weeks of May, in order to secure the most appropriate data for statistical analysis of population size, dynamics, and movements in this intensively-studied population (the best data on any population of the Schaus Swallowtail are available on this key's population, from the field surveys of Charles Covell in the early 1970's to the intensive field surveys there of the present investigators in 1984 and 1985). Then the focus will shift to assessing population levels and occurrence on Key Largo, Old Rhodes Key, Totten Key, and the other keys in Biscayne Bay and to the south of Key Largo. The entire former distributional area for the Schaus Swallowtail will be checked, and the 1986 status of hammocks, foodplants, congener species (especially the potential competitor, the Giant Swallowtail, Papilio cresphontes), and other parameters. A final two-year data analysis will be carried out and completed, with the Final Report projected for submission by July 30, 1986, together with copies of manuscripts of proposed publications.

Simultaneously at the University of Florida, work will continue on the effects of the mosquito-control spraying components and field monitoring equipment will be placed and data recorded on northern and southern Key Largo, as per the project outlined to the Dunn Foundation. Consultations will be held in April with Don Wood and the Nongame Wildlife Program Office concerning the advisability of any further attempts at captive rearing of ponceanus and the possible direct transfer of eggs, larvae, pupae or adults from an abundant 1986 population area to a presently-uninhabited hammock area, for possible re-establishment of this butterfly elsewhere in the Keys.