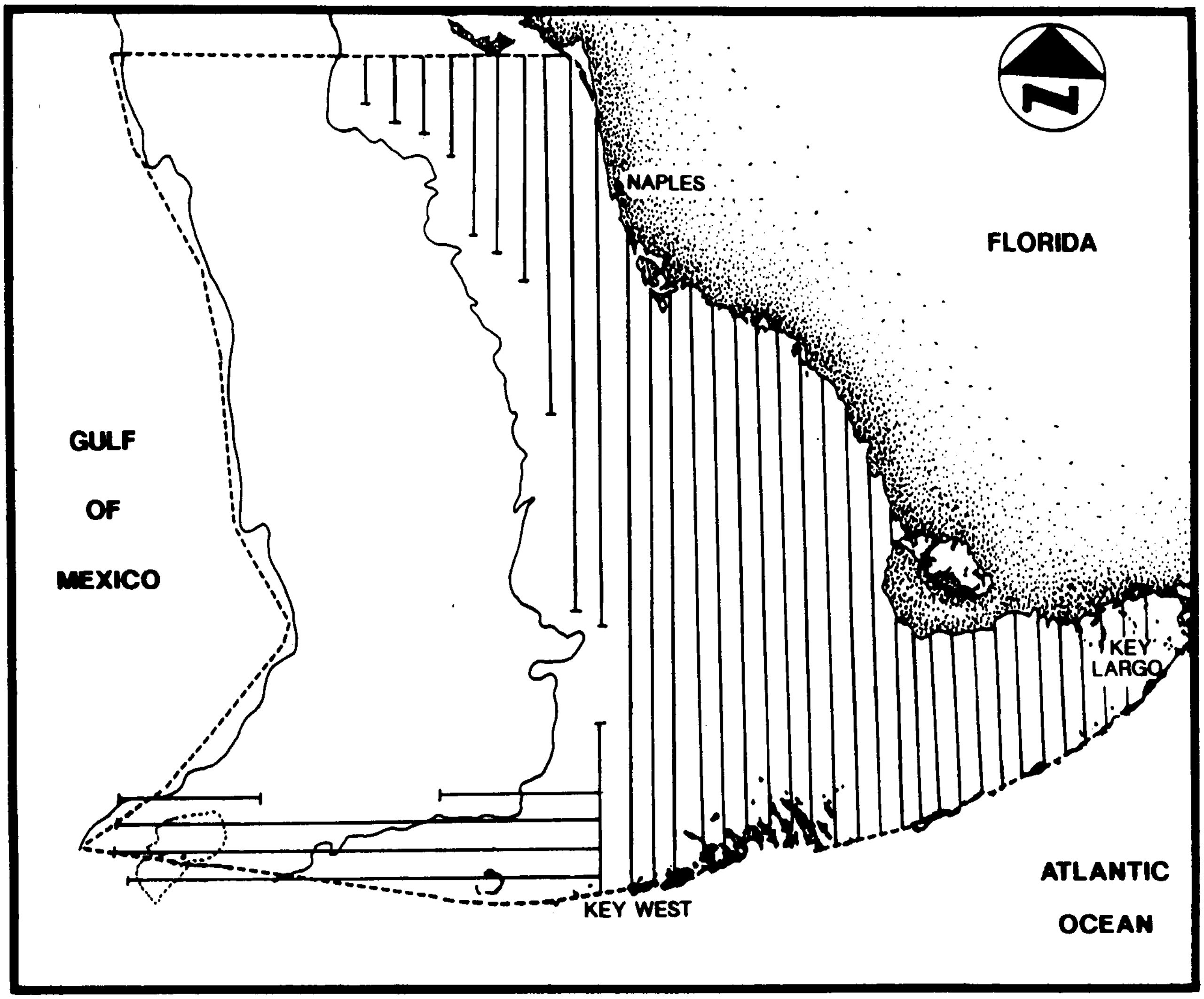
OCS Study
MMS 89-0080

Southwest Florida Nearshore Benthic Habitat Study

Narrative Report



U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

OCS Study
MMS 89-0080

Southwest Florida Nearshore Benthic Habitat Study

Narrative Report

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ABSTRACT

Habitat distributions within 9,627,000 ac (3,896,047 ha or 15,042 mi^2) of the southwest Florida nearshore continental shelf were mapped. Within 5,006,000 ac (2,025,928 ha), habitat distributions were mapped from aerial imagery. In an additional 4,622,000 ac (1,870,523 ha), habitat distribution patterns were extrapolated from ground survey data.

Four, geomorphically distinct sub-areas exist within this study area: 1) the inner southwest Florida continental shelf, dominated by low-relief hard and soft coral communities and *Halophila decipiens* stands; 2) Florida Bay, dominated by communities of *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii*; 3) the Lower Florida Keys, dominated by *Thalassia*, *Syringodium*, and *Halodule* stands and patch reefs; and 4) the Tortugas/Marquesas Reef Banks, dominated by sand banks and coral reefs.

In terms of area, the deep-growing seagrass stands of *H. decipiens* were the most widely distributed habitat surveyed. These seagrass communities covered 3,004,000 ac (1,215,719 ha) of the inner southwest Florida continental shelf, or 31% of the entire mapped area.

No *Halophilia engelmannii* was seen anywhere on the southwest Florida continental shelf during this study. The absence of this species is conspicuous since it has previously been reported from the southwest Florida shelf, and was abundant on the northwest Florida continental shelf (Big Bend area) during studies conducted in 1984 and 1985. No explanation for its absence off southwest Florida during the 1988 sampling period has been advanced.

Halophila decipiens appears seasonally on the west Florida shelf, beginning in late May and early June. These deep seagrass beds grow rapidly and reach a peak standing crop in late September. Following this biomass peak, new blade production drops off and beds begin to deteriorate. Rhizome structure weakens, and these beds are washed away with the onset of severe winter weather.

Halophila decipiens biomass peaked in the 70 to 90 ft (21.3 to 27.4 m) depth range. Deeper than 100 ft (30.5 m), *H. decipiens* began to be replaced by a long-bladed form of *Caulerpa prolifera* in suitable growth substrates. No *H. decipiens* was seen at depths >122 ft (37.2 m).

Mean biomass of *H. decipiens* across the inner southwest Florida continental shelf was 194.0 mg/m^2 in September 1988. Extrapolation from this figure yielded a standing crop estimate of 2,600 tons (2,359 metric tons). The fate of this organic material within the continental shelf ecosystem is not well understood. Very little of it is eaten directly. Some of the disintegrated leaves appear to enter the detrital food chain, while others may be swept off the continental shelf to become a potential food source in deeper waters.

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1.0 INTRODUCTION

1.1 STUDY RELEVANCE

The Outer Continental Shelf (OCS) Environmental Studies Program is designed to provide critical environmental data for leasing and lease-management decision making regarding offshore petroleum exploration and development. Within the eastern Gulf of Mexico, the Minerals Management Service (MMS) has sponsored a wide variety of information-gathering and synthesis studies, including regional reconnaissance, area-specific, and environmental-process-specific studies.

The Southwest Florida Nearshore Benthic Habitat Study was designed to provide information on habitats and sessile biota (seagrasses and hard and soft corals) in shallow water along the southwest Florida coast. This study supplements offshore studies of habitat diversity and distribution previously funded by the MMS in deeper waters of the southwest Florida continental shelf (Continental Shelf Associates, Inc., 1985; 1987a). It also continues a series of studies on the distribution and productivity of seagrass beds and nearshore habitats on the west Florida continental shelf begun by the MMS in the Florida Big Bend area (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985; Continental Shelf Associates, Inc., 1987b; Thompson and Phillips, 1987).

Extensive natural resources that might be affected by oil and gas drilling and production are known to exist in the area covered by this study (Figure 1.1). Public hearings in Florida regarding potential offshore oil exploration in the area south of 26°N have shown significant public concern over potential damage to these resources. It is important to determine the extent and distribution of resources in this area so that they may be adequately protected.

Two seagrass species of *Halophila*, *H. decipiens* and *H. engelmannii*, reported from the southwest Florida continental shelf occur seasonally. The fact that these seasonal, fringing species extend into deep water off the Florida west coast has been known for some time (Zieman, 1982; Iverson and Bittaker, 1986). However, the extent of such seagrass growth (in terms of acreage) only began to be realized in 1985, with the completion of the Florida Big Bend Seagrass Habitat Study (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985; Thompson and Phillips, 1987). The seasonal presence of these deep seagrass beds is an important element in managing petroleum exploration on the southwest Florida nearshore continental shelf.

This study provides data necessary for the preparation of Environmental Impact Statements (EISs) associated with the offshore leasing process, the preparation of regional and lease site specific Environmental Reports (ERs), assignment of lease block exploratory drilling stipulations, environmental monitoring, and oil spill contingency planning.

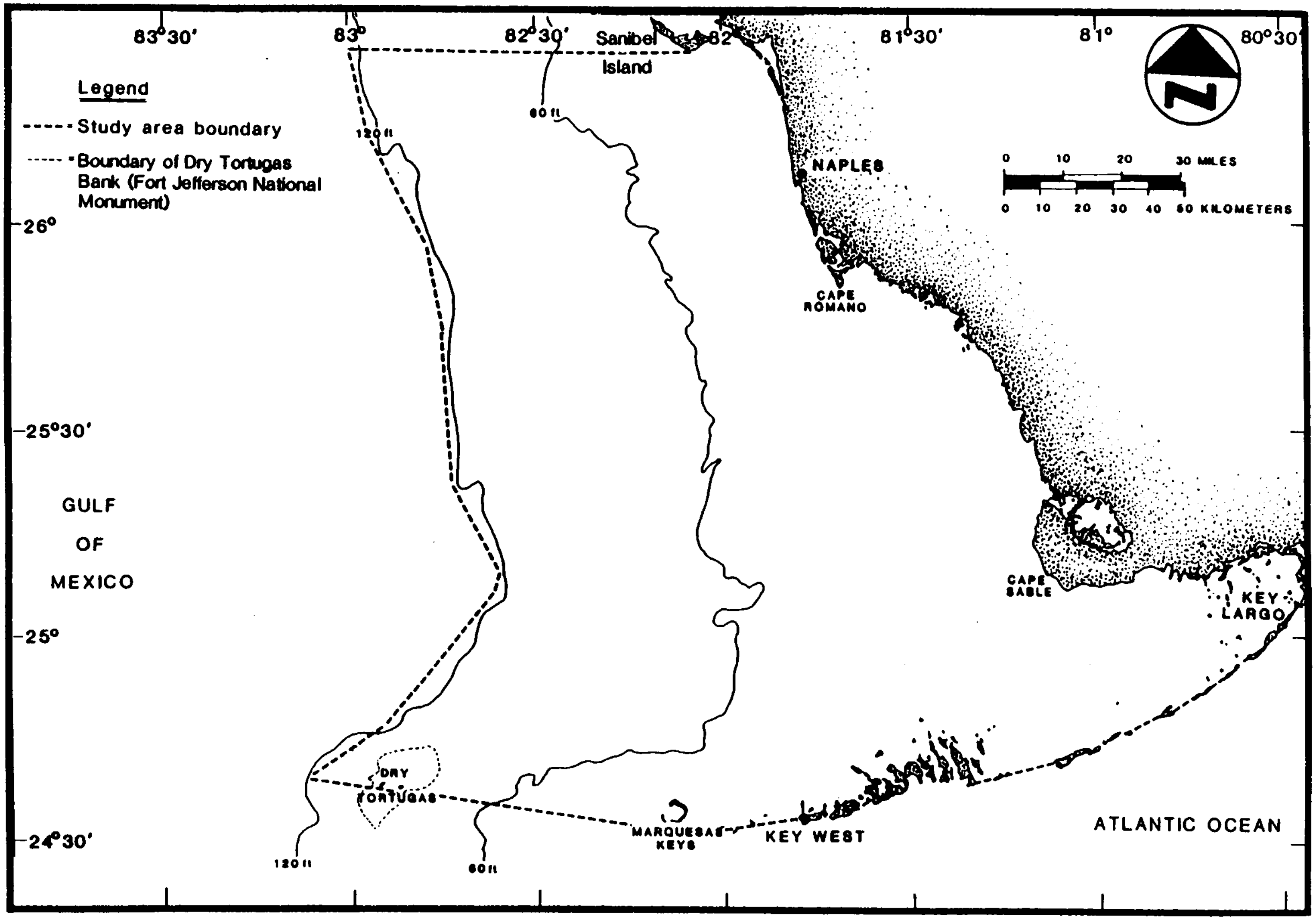

Figure 1.1. The study area.

1.2 OBJECTIVES

Specific objectives of this study were:

1) To map and inventory seagrass beds and habitats formed by sessile invertebrates along Florida's southwest coast, within Florida Bay, and along the north side of the Florida Keys to Dry Tortugas, using a combination of aerial photography and shipboard ground truthing; and

2) To determine the seasonal growth period and seaward extent of deep seagrass beds formed by *Halophila* spp. throughout the study area.

1.3 PRODUCTS

Final products from this study consist of:

1) This narrative report;

2) A two-volume set of atlases showing mapped habitat distributions at a scale of 1:40,000 throughout the study area;

3) A composite, 1:250,000 scale, map showing habitat distribution patterns area-wide superimposed on OCS lease blocks; and

4) Aerial imagery at a scale of 1:40,000 covering the study area.

2.0 METHODS

2.1 OVERVIEW

Originally, the Southwest Florida Nearshore Benthic Habitat Study was planned as a two-part effort:

1) Remote mapping with aerial imagery; and

2) Ground truthing to quantify mapped habitats and to survey deep seagrass beds beyond the detection capabilities of remote imagery.

However, one of the major objectives of this study was to determine the extent and maximum depth of growth of the deep seagrass beds known to occur along the southwest Florida continental shelf. Deep-growing seagrass (*Halophila* spp.) and macroalgal stands have been reported to a depth of 80 ft (24 m) in the Florida Big Bend area (Iverson and Bittaker, 1986; Thompson et al., 1989), and similar communities exist on the southwest coast of Florida (Continental Shelf Associates, Inc., 1987a).

Due to poor weather conditions, ground truthing field work on the South Florida Nearshore Benthic Habitat Study did not begin until 11 November 1987. Once in the field, the survey team immediately noted the absence of deep seagrass and algal stands which were to be mapped. Ground truthing was discontinued at that point until 1988, and the study was expanded to include a set of short surveys to determine appearance dates and growth rates of seagrass species comprising these deep, offshore beds. Table 2.1 provides a complete chronology of field efforts.

2.2 HABITAT MAPPING

2.2.1 Remote Imagery

Between the 4th and 9th of October 1987, 39 flight lines were flown across the study area (Figure 2.1). This flight plan was developed based on the boundaries which extended along the entire southwest Florida coastline from Sanibel Island through Florida Bay, westward along the Florida Keys to the Dry Tortugas Bank (Fort Jefferson National Monument), and northward from the Marquesas to a point about 25 nmi (46 km) west of Sanibel Island. This design included all areas along the southwest Florida continental shelf lying in <50 ft (15 m) of water. The 50-ft (15-m) bathymetric contour was arbitrarily chosen as the cutoff point for attempted remote imagery acquisition, based on our experience in the Florida Big Bend project (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985). In that study, the maximum depth at which features could be resolved on the bottom was 45 ft (14 m).

Actual shelf area covered by the overflights was considerably more than that precisely within the 50-ft (15-m) contour, due to side-lap and overlap of the individual photoframes. Particularly good imagery, which resolved the bottom to a depth >50 ft (15 m), was

Table 2.1. Chronological order of field efforts.

Aerial Overflight	4-9 October 1987
First Ground Truth Survey Attempt	11-14 November 1987
First Short Seagrass Growth Monitoring Survey	8-10 June 1988
Second Short Seagrass Growth Monitoring Survey	5-8 July 1988
Third Short Seagrass Growth Monitoring Survey	1-4 August 1988
Major Ground Truthing Survey	20 September - 4 October 1988
Fourth Short Seagrass Growth Monitoring Survey	29 November - 1 December 1988
Fifth Short Seagrass Growth Monitoring Survey	5-7 January 1989

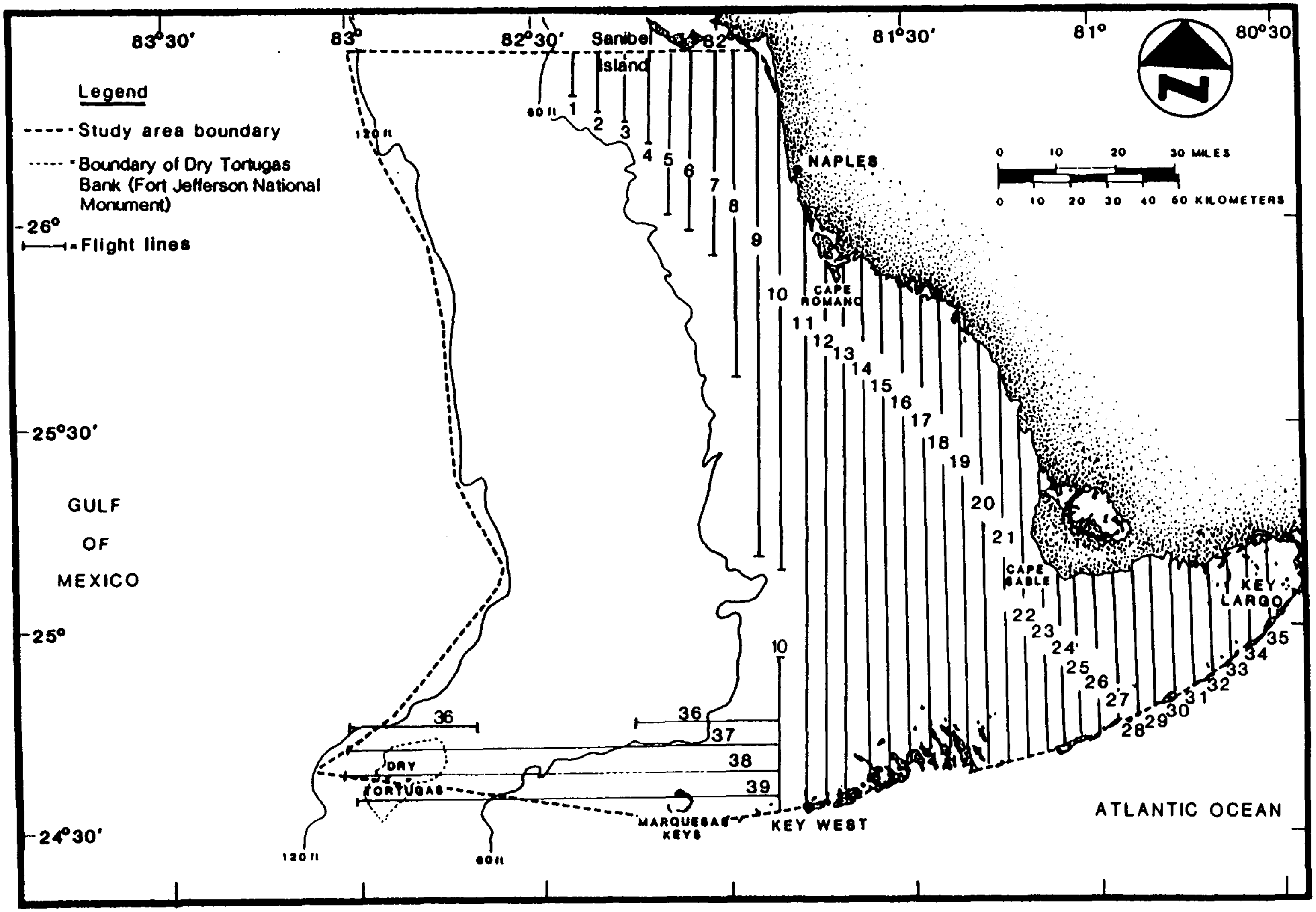

Figure 2.1. Diagram of aerial flight lines.

acquired in the area north of the Lower Florida Keys and off Dry Tortugas.

Navigation was controlled using Loran-C. At the scale of 1:40,000, the flight lines were accurate within 1,000 ft (305 m) of their mapped position. This tolerance is well within normal photomapping flight-line precision.

On 27 September, a test strip of film was exposed and processed to calculate exposure setting for the cameras. An intervalometer was coupled to the Loran-C real-time ground speed indicator to insure that each frame contained the proper amount of forward overlap (60%).

Five rolls of standard photogrammetric, 9 x 9 in. format, Kodak Ecktachrome color transparency film, were utilized for this survey. The scale on all imagery was 1:40,000, or 1 in. equals 3,333 ft (2.5 cm = 1,016 m) on the actual color transparency.

As each roll of film was completed, it was forwarded to Precision Photo Laboratories, Inc., in Dayton, Ohio for processing. Processed rolls were returned to Chicago Aerial Survey where the date and center latitude and longitude coordinates, taken from the navigational logs, were entered in the margins of each photoframe.

2.2.2 Ground Truthing

All annotated film was returned to Martel Laboratories, Inc. in St. Petersburg, Florida. A review of the imagery covering the entire study area was held on 9 November 1987 at the Martel facilities. Those attending were the Continental Shelf Associates, Inc. (CSA) Program Manager, the Martel Laboratories, Inc. (Martel) Program Manager, and the Minerals Management Service Contracting Officer's Authorized Technical Representative. Objectives for this review were to:

1) Check the quality of the overall imagery;

2) Finalize the locations for ground truth survey transects; and

3) Select specific sites where signature verification of imagery-resolved bottom features was required.

At that meeting, 12 potential ground truth survey transects were established, and seven specific sites where signature verification was necessary were identified.

Initial ground truthing of the remotely collected imagery was attempted on 11 November 1987, but the early die off of deepwater _H. decipiens_ seagrass beds forced a postponement of this effort.

During 1987, a major, late season, tropical depression passed through the study area following the October overflights. When the ground truth team entered the field in November, they noted that the seagrasses in the 70 to 90 ft (21 to 27 m) depth range had died off for the 1987 growing season. Since one of the primary objectives of this research program was to discover the depth and density of seasonal seagrass growth off southwest Florida, it was decided to postpone the major ground truthing survey until the peak of the 1988 growing season.

Ground truthing of the October 1987 aerial imagery began again on 20 September 1988. Figure 2.2 shows the location of all transects and stations sampled between 20 September and 4 October 1988.

Two methods of data collection were employed on this survey:

1) Bounce dives by teams of scientific divers at pre-selected stations; and

2) Diver, television, and still camera tows along pre-selected transects.

Bounce dives were conducted for signature verification in terms of habitat present at a specific location (e.g., dense soft coral flats, sparse nearshore seagrass beds, etc.) and for the collection of quantitative data at all stations containing significant Halophila spp. growth.

Quantitative data were collected by the diving scientists using a photographic technique described by Continental Shelf Associates, Inc. in 1985 and refined in subsequent studies in 1986 and 1987 (Continental Shelf Associates, Inc, 1985; 1987b; Thompson et al., 1989.). This technique involves collection of 10 phototransparencies, using an underwater camera mounted on a framing device. This framing device has a 0.1 m^2 data-collection area and insures that each frame is exposed from exactly the same distance above the subject. Because of the low, sparse growth form of deepwater Halophila spp., this technique allows precise leaf counts and measurements to be taken from each photoframe. Ten photoframes were randomly taken in all areas showing Halophila spp. growth.

Blades per m^2 and biomass for the Halophila stands were determined by following procedures outlined in Continental Shelf Associates, Inc., 1988, Thompson et al., 1989, and Appendix A. All blades in each photoframe were counted, but in general only 60 to 80% of the blades seen could be measured. Measured blades were divided into length classes (i.e., 0 to 5 mm, 6 to 10 mm, etc.). It was assumed that the percent composition of a leaf class within the measured sample represented the percentage that leaf class made up in the total sample count. For example, if 80 blades were counted in a given frame and 70 blades were measured, and if blades ranging from 6 to 10 mm in length made up 30% of the 70 blades measured, they would represent 30% of the total 80 blades present, yielding a calculated value of 24 (6 to 10 mm) blades in the sample.

Numbers of blades for each leaf length classification in each of the 10 photoframes counted were summed. Using a mean dry weight biomass for leaves in each blade length class, biomass per m^2 was estimated for each sampled seagrass station.

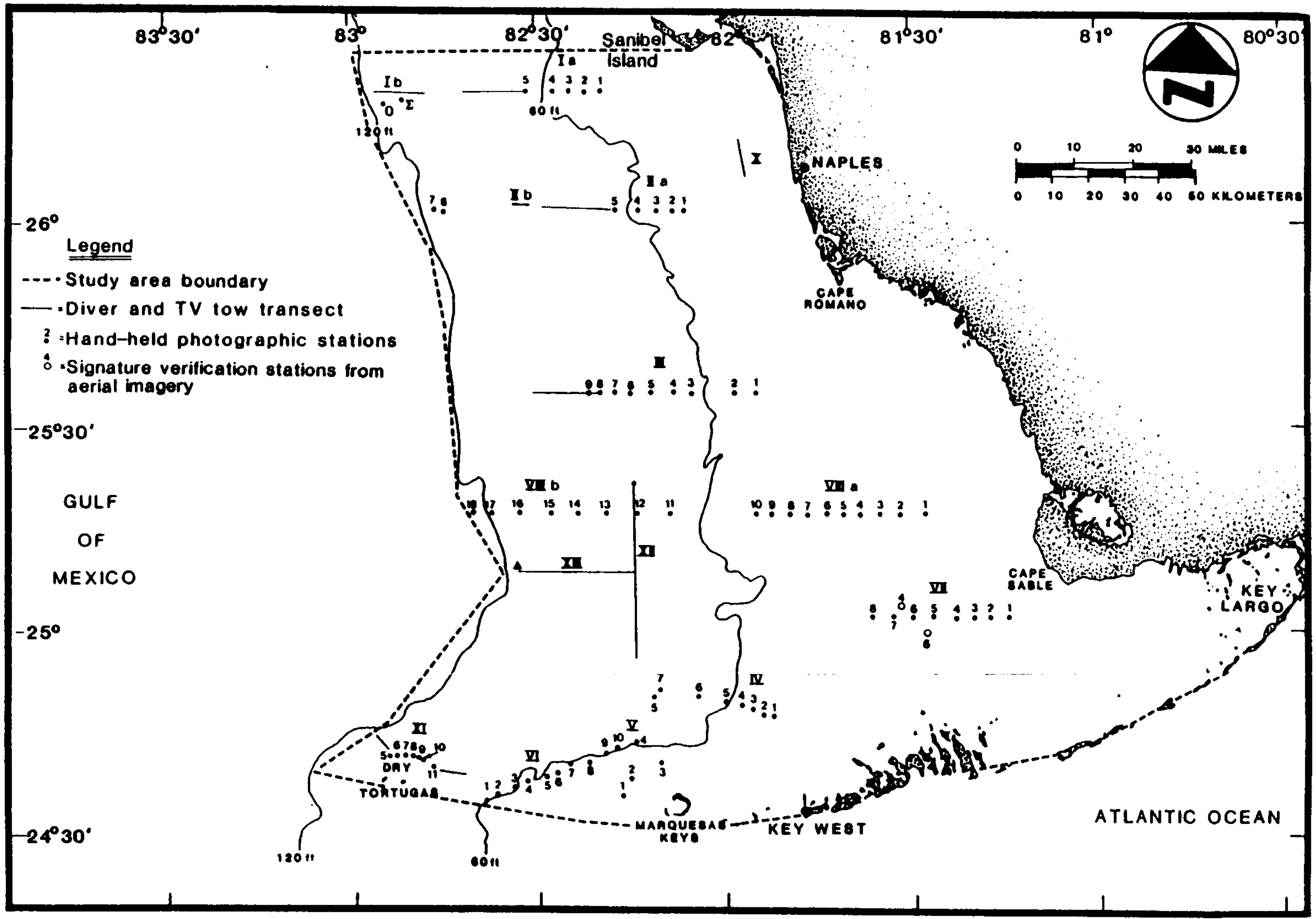

Figure 2.2. Ground truth survey, diver and television transects and quantitative, hand-held photographic stations.

Quantification of organism densities within the soft and hard coral flat required that many photographs be taken across these habitats. To accomplish this, an underwater benthos camera was mounted on the diver/television tow sled in such a way as to point vertically at the bottom. The underwater television allowed the sled's operator, located aboard the survey vessel, to insure that a constant altitude above the bottom was maintained while all bottom photographs were taken.

Quantitative photographs taken with the benthos camera in areas of hard and soft coral habitats were divided into sets (100 frames each) based on the observed density of organisms present. These sets of photographs were then analyzed to determine percent coverage of all biotal groups seen in the frame, utilizing a random point technique described by Bohnsack (1976, 1979) and used in previous studies of the southwest Florida shelf ecosystem (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983, 1985; Continental Shelf Associates, Inc., 1987a; Environmental Science and Engineering, Inc. et al., 1987). The percent cover values (providing ranges) were then used to describe mapping habitat classifications.

Identification of specific coral and sponge biota associated with these hard and soft coral flats was beyond the scope of this project. General taxonomic descriptions for these continental shelf communities are provided in Continental Shelf Associates, Inc. (1987a) and Environmental Science and Engineering, Inc. et al. (1987). This study concentrated only upon the density of organisms in the various density-based mapping classifications.

Qualitative data from television and still camera records, and diver observations, were used to determine overall habitat trends across the study area. Diving scientists recorded information immediately after each bounce dive, as well as provided continuous descriptions of the bottom as they were being towed underwater. Detailed observational and navigational logs were kept throughout all phases of this survey and were used in the review and analysis of ground survey data.

2.2.3 Data Synthesis and Mapping

All photointerpretation and mapping took place at the Martel Laboratories, Inc. facilities in St. Petersburg, Florida. Initially, all aerial photography was reviewed, catalogued, and positioned along respective flight lines. Not all portions of a given flight line were necessarily flown on the same day. Occasionally, cloud build-up or other logistic considerations forced a flight line to be broken off, and later resumed. The first task in the interpretation process was to organize each flight line into a complete data set of photographs.

Photointerpretation and construction of the final maps contained in the atlases accompanying this report incorporate all the ground truth data obtained from the November 1987 cruise, the five, three-day seasonal surveys conducted between June 1988 and January 1989 (see Section 2.3.1), and the major ground truth survey conducted between 20 September and 4 October 1988. All photointerpretation and habitat mapping was based on a predetermined set of habitat density/distribution pattern codes (Table 2.2).

The photointerpretation and mapping process consisted of an initial meeting and review of all imagery and ground data by CSA and Martel Program Managers. At this meeting, all classification codes were reviewed and revised, selected areas were jointly interpreted by both principal investigators, and the photointerpretation team was briefed using the jointly interpreted frames as examples.

Following initial interpretation of all imagery, and development of the initial map and atlas layouts, another meeting was held between contract principals and the interpretation team. This meeting reviewed areas of potentially ambiguous classifications and finalized the presented map formats, based on a review of a draft map sheet by the MMS.

Final atlas maps represent a direct transfer at a scale of 1:40,000 of the photointerpreted data. They utilize National Oceanic and Atmospheric Administration (NOAA) navigational charts enlarged to the proper scale as base maps, and all data transfer conforms to standard cartographic procedures. Key maps and locational guides for flight lines and individual photoframes are provided within the atlases. The larger scale, 1:250,000 composite map showing the entire study area and habitat distribution assumed from ground truth data (i.e., habitat distribution in the portions of this study area beyond the depth where aerial imagery effectively resolves the bottom) utilizes an MMS lease block map for its base. Data from the 1:40,000 interpreted photography maps were photographically reduced and transferred to the composite map again, following standard cartographic procedure.

2.3 SEAGRASS GROWTH CYCLE STUDY

2.3.1 Field

Twenty-seven seasonal sampling stations were established (Figure 2.3) using the 1987 aerial imagery and data from a previous study (Continental Shelf Associates, Inc., 1988). These stations were sampled in June, July, August, and December of 1988, and in January of 1989.

The major ground truthing cruise took place between 20 September and 4 October 1988; but due to the extensive area this cruise had to cover, only three of these growth-monitoring stations were resampled during that time period (Stations 16, 17, and 18). Seagrass size and weight data were, however, collected shelf-wide on that survey (Figure 2.4).

The same photographic data-collection techniques described for quantitative *Halophila* stations on the major ground truth survey (see Section 2.2.2) were employed for the seasonal growth rate monitoring study. Ten randomly located, replicate photographs were taken at each station on each survey.

Table 2.2. Classification codes of mapped habitats.

Habitat Type and Description	Code
Dense nearshore seagrass beds = Seagrass beds dominated by _T_. _testudinum_, _S_. _filiforme_, and _H_. _wrightii_.	1
Uniform = dense nearshore seagrass beds in which coverage is continuous across large areas of the bottom.	1a
Patchy = nearshore seagrass beds which form individually dense stands of seagrass, but in which large expanses of bare bottom may be seen between the individual stands.	1b
Sparse nearshore seagrass beds = Seagrass beds of one or more of the three nearshore species showing a reduced cover in terms of blades per unit area.	2
Uniform = sparse nearshore seagrass beds where coverage is continuous across a large area of bottom.	2a
Patchy = sparse nearshore seagrass beds which show large areas of open bottom between stands.	2b
Dense offshore _Halophila_ sp. and rhizophytic algal stands (>30% bottom cover). We combined the rhizophytic algae with _Halophila_ in this category because both species are usually seen growing together in offshore areas. Although monotypic stands of algae and _Halophila_ are occasionally seen, these cannot be differentiated from the aerial imagery.	3
Uniform.	3a
Patchy.	3b
Sparse offshore _Halophila_ sp. and rhizophytic algal stands. Offshore stands of _Halophila_ and algal species (<30% bottom cover).	4
Uniform.	4a
Patchy.	4b
Non-vegetated sand bottom.	5
Sand and shell hash.	5a
Silty sand - sandy silt.	5b
Non-vegetated mud bottom.	6

Table 2.2. (Continued).

Habitat Type and Description	Code
Dense soft coral flats = Dense, low-relief, live-bottom areas based on the number of organisms per unit area.	7
Uniform.	7a
Patchy.	7b
Sparse soft coral flats = Sparse, live-bottom areas based on the number of individuals per unit area.	8
Uniform.	8a
Patchy.	8b
Scattered coral patch reefs.	9
Continuous coral reef.	10
Sparse nearshore seagrass interspersed with dense patches. This habitat occurs in karst substrates covered with a thin sediment layer which supports a uniform but sparse seagrass community, and where occasional dense seagrass patches are seen growing in solution features.	11
Hard bottom areas where sparse corals and gorgonids are interspersed with occasional dense patches of seagrass. These hard bottom areas support a uniform but extremely sparse seagrass coverage, and occasionally show dense, circular seagrass stands.	12

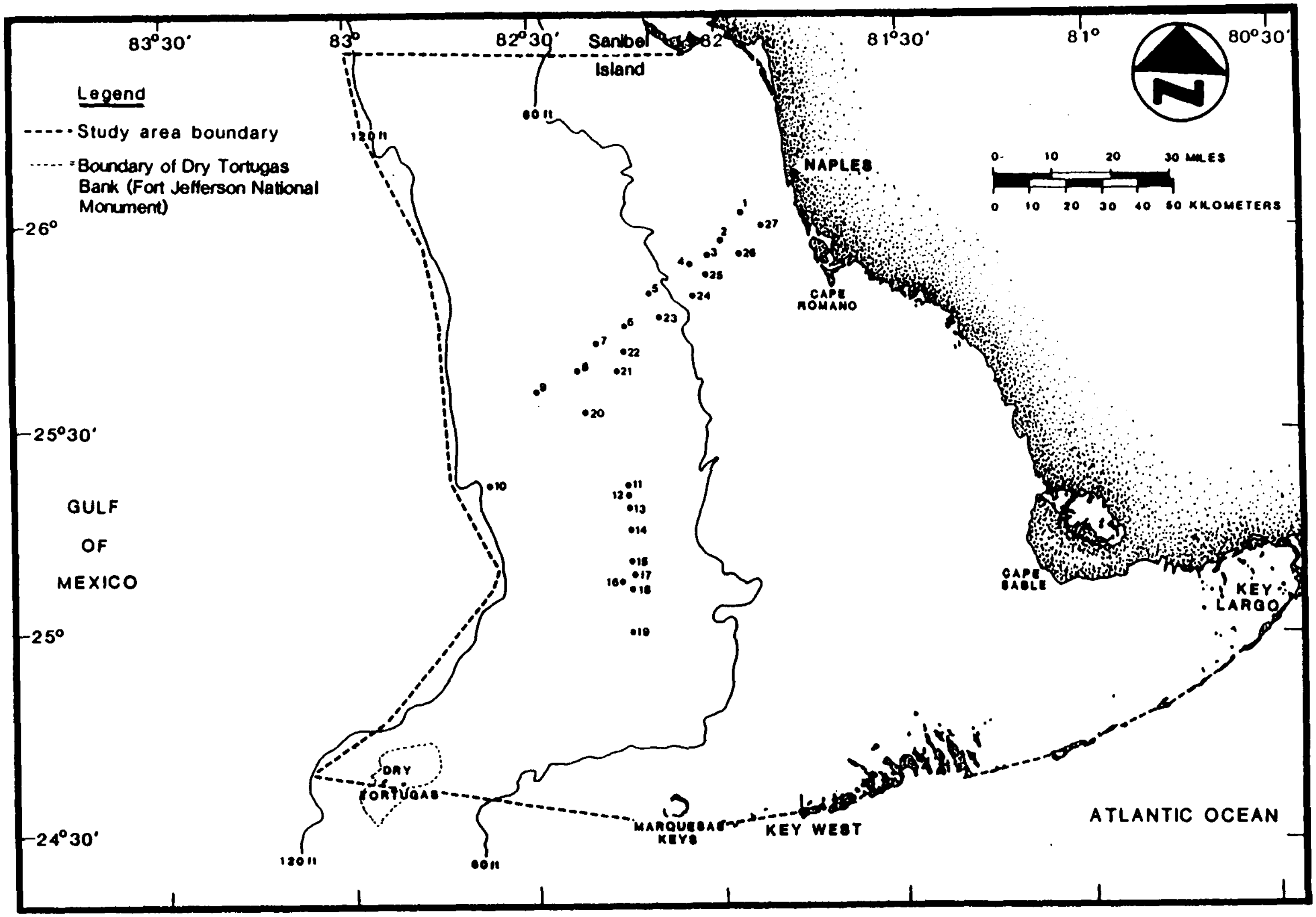

Figure 2.3. Seagrass stations sampled on short cruises in June, July, August, and December 1988 and January 1989.

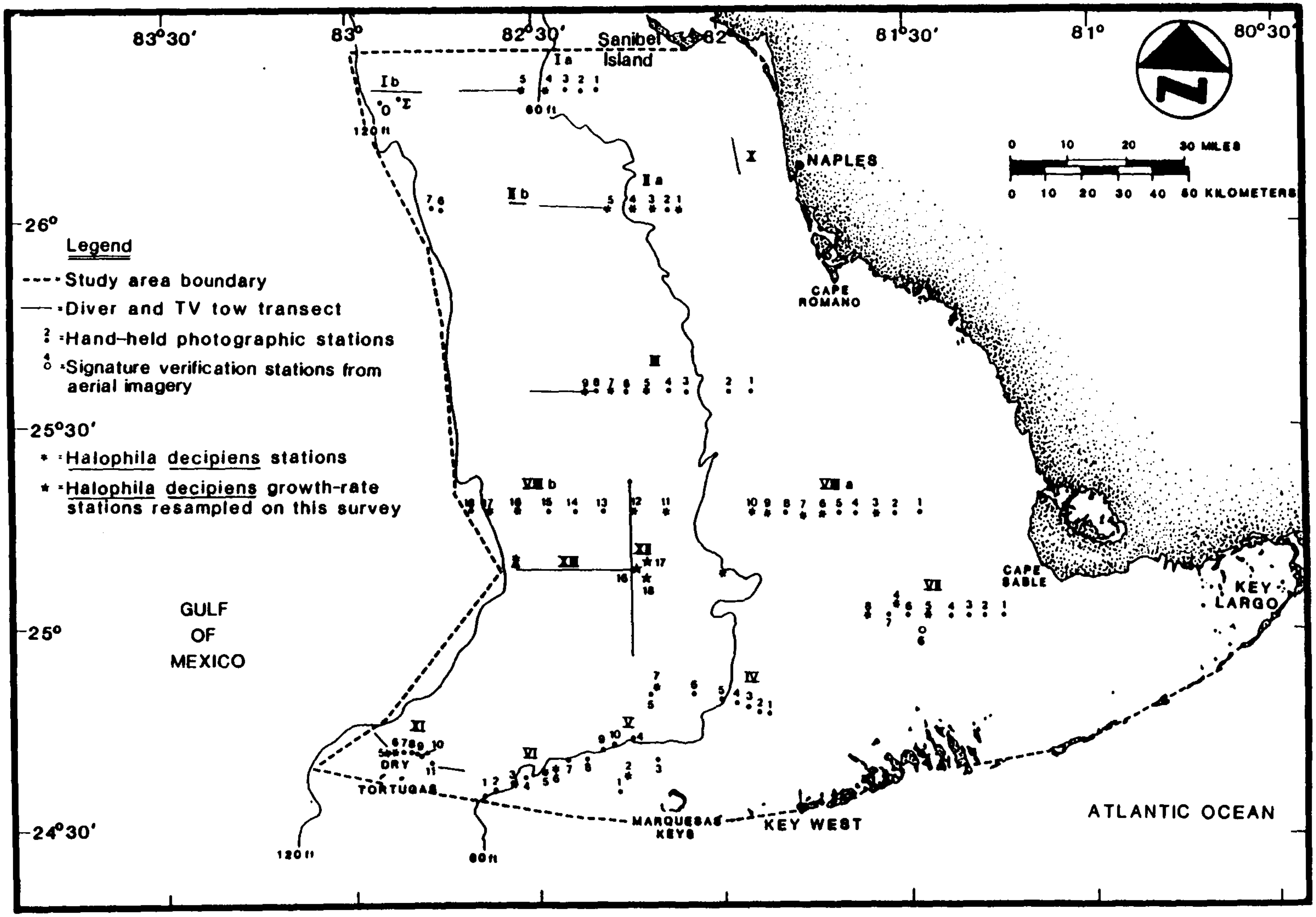

Figure 2.4. Halophila decipiens stations sampled during the ground truthing survey of 20 September to 4 October 1988.

2.3.2 Analysis

All film was processed in the field at the time of data collection in order to insure sampling cameras had worked properly. When returned to the laboratory, each phototransparency was projected onto a screen and the Halophila blades present were counted and measured (see Section 2.2.2 and Appendix A). Blade counts and biomass calculations were used to assess seasonal growth rate and productivity for these seagrasses throughout the 1988 growing season.

3.0 RESULTS

3.1 HABITAT MAPPING

The study area (Figure 1.1) covers approximately 9,627,000 ac (3,896,047 ha or 15,042 mi^2). Habitat distributions within 5,006,000 ac (2,025,928 ha) were mapped from the aerial imagery. Habitat distributions within another 4,622,000 ac (1,870,523 ha), essentially that portion of the study area deeper than 45 ft (13.7 m), were mapped based on extrapolations from the ground truthing survey (Figure 3.1).

Ground survey efforts were concentrated in deeper waters for three reasons:

1) Beyond the 45-ft (13.7-m) bathymetric contour, aerial imagery is ineffective for mapping submerged habitat distribution;

2) The MMS jurisdiction lies beyond the three league line off west Florida; and

3) Critical nearshore habitats, such as those seen in the Florida Keys and Florida Bay, are well documented, if not well mapped, within the scientific literature while those in deeper water are not.

The dense (1a and 1b) or sparse (2a and 2b) nearshore seagrass habitats (Table 2.2) were not extensively surveyed on the ground because they apply specifically to habitats seen close to shore or within Florida Bay. These classifications cover perennial seagrass beds formed by the species Thalassia testudinum, Syringodium filiforme, and Halodule wrightii.

The classifications relating to scattered, coral patch reefs (9) and continuous, coral reef flats (10) were seen only along the Tortugas Bank during ground truthing (Table 3.1), but were mapped from the aerial imagery throughout the Marquesas and Lower Florida Keys.

At the southern tip of the Florida peninsula, geologic and environmental conditions are more closely associated with the tropical Caribbean than with the rest of the Gulf of Mexico. These environmental and physical characteristics produce seagrass growth patterns and mapping signatures differing for other areas of Florida such as the Indian River or the Florida Big Bend area.

In large areas of Florida Bay, there is a thin layer of sediment over a hard, karst substrate. Within this substrate there are characteristic large circular features which mark the positions of old mangrove stands inundated by sea level rise. Across these areas sparse but uniform seagrass is seen growing in the thin sediment above the karst crust. Where sediments have accumulated, in the old mangrove pockets, dense circular seagrass stands are seen. No density range is given for seagrasses in these type habitats (11) because they represent

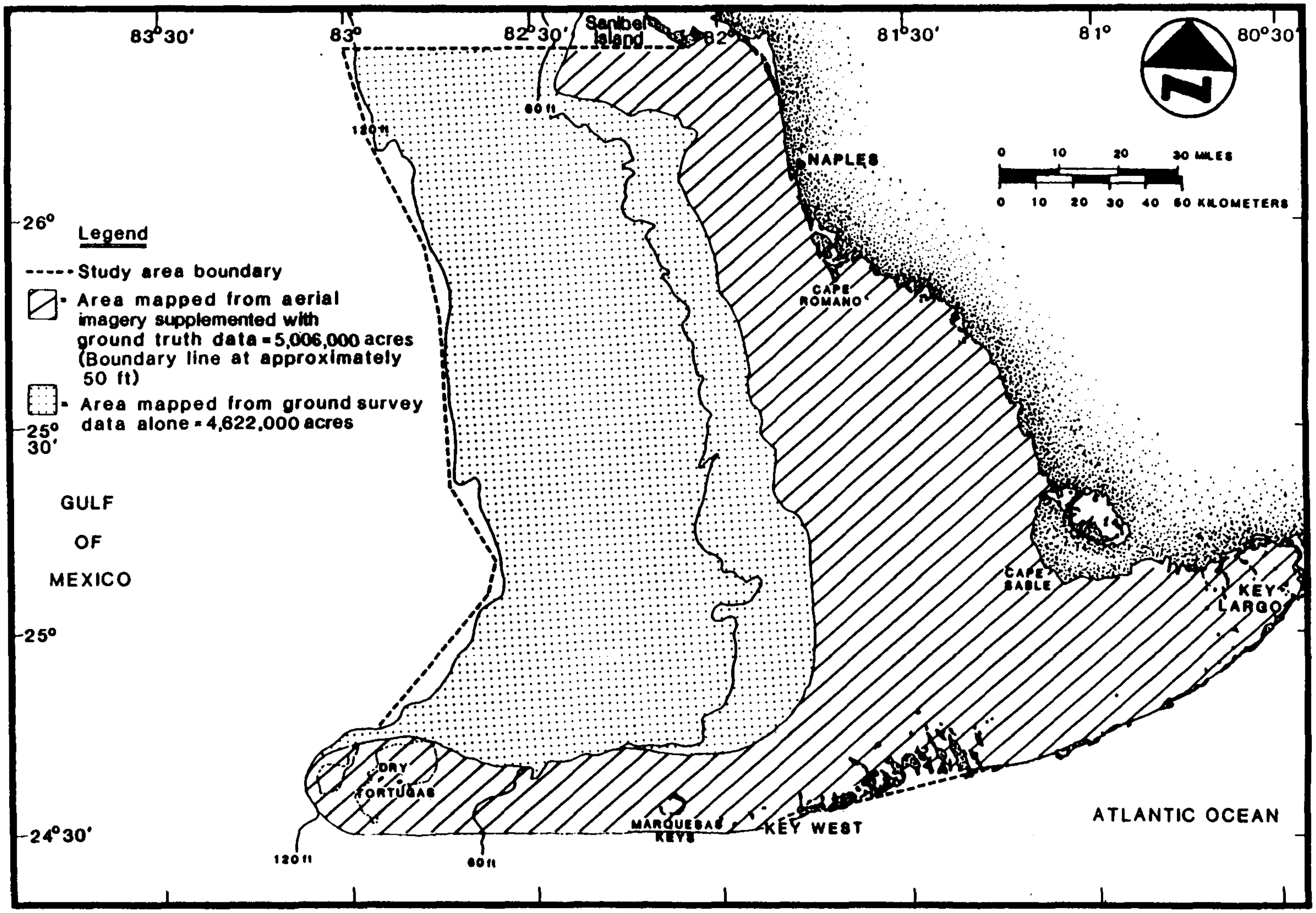

Figure 3.1. Proportions of the study area mapped using aerial imagery supplemented with ground truthing data, and the portion mapped based on ground surveying alone.

Table 3.1. Location, qualitative description, depth, and habitat classification of diver-photographed, ground-truth sampling stations.

Station	Latitude	Longitude	Description	Depth (ft)	Classification
I-1	26°19.48	82°19.90	Very sparse live bottom	54	8a
I-2	26°19.48	82°22.48	Bare sand	56	5a
I-3	26°19.48	82°25.48	Bare sand	58	5a
I-4	26°19.48	82°28.48	Uniform sparse *H. decipiens*	70	4a
I-5	26°19.48	82°31.48	Uniform dense *H. decipiens*	75	3a
II-1	26°01.92	82°03.06	Patchy *H. decipiens*	48	3b
II-2	26°01.92	82°06.06	Bare sand	55	5a
II-3*	26°01.92	82°09.06	Sparse, patchy *H. decipiens*	58	4b
II-4	26°01.92	82°12.06	Sparse live bottom	59	8a
II-5	26°01.92	82°15.06	Sparse live bottom with *H. decipiens*	66	8b
III-1	25°35.00	81°55.00	Bare sand	55	5a
III-2	25°35.00	81°58.00	Low density live bottom	62	8a
III-3	25°35.00	82°01.00	Dense uniform live bottom	66	7a
III-4	25°35.00	82°04.00	Dense *Caulerpa* sp., sparse coverage	69	4a
III-5	25°35.00	82°07.00	Sparse, patchy *H. decipiens*	78	4b
III-6	25°35.00	82°10.00	Bare sand with bluegreen algae	82	5a
III-7	25°35.00	82°13.00	Sparse uniform *H. decipiens*	86	4a
III-8	25°35.00	82°16.00	Bare rubble bottom	87	5a
III-9	25°35.00	82°19.00	Dense uniform *H. decipiens*	92	3a
IV-1	24°46.80	81°48.50	Silty clay bottom	53	5b
8*	24°45.00	81°51.50	Sparse live bottom	52	8a
IV-2	24°47.20	81°51.50	Silty clay bottom	57	5b
IV-3	24°47.20	81°54.30	Silty clay bottom	59	5b
IV-4	24°48.70	81°57.30	Silty clay bottom	63	5b
IV-5	24°49.20	82°00.70	Silty clay bottom	68	5b
IV-6	24°50.00	82°03.30	Silty clay bottom	72	5b
IV-7	24°51.20	82°09.50	Sparse uniform *H. decipiens*	77	4a
V-1	24°35.48	82°16.23	Mixed stand *Thalassia*, *Syringodium*, and *Halodule*	28	2a
V-2	24°37.80	82°15.50	Medium density live bottom	40	8a
V-3	24°40.50	82°14.40	Medium density live bottom	46	8a
V-4	24°43.10	82°13.00	Silty clay bottom	68	5b
V-5	24°49.90	82°10.20	Silty clay bottom	80	5b
VI-1	24°35.00	82°38.00	Dense uniform live bottom	75	7a
VI-2	24°35.50	82°35.50	Dense uniform live bottom	46	7a
VI-3	24°36.50	82°33.00	Sparse, patchy *H. decipiens*	56	4b
VI-4	24°37.50	82°31.00	Bare sand	65	5a
VI-5	24°38.09	82°27.82	Sparse, patchy *H. decipiens*	42	4b
VI-6	24°38.50	82°26.33	Sparse uniform *H. decipiens*	42	4a
VI-7	24°39.90	82°24.00	Bare sand	34	5a
VI-8	24°40.09	82°21.33	Bare sand	35	5a
VI-9	24°41.50	82°18.80	Silty clay bottom	59	5b
VI-10	24°42.50	82°16.50	Silty clay bottom	62	5b
VII-1	25°01.94	81°12.80	Sparse uniform live bottom	18	8a
VII-2	25°01.94	81°15.80	Sparse uniform live bottom	18	8a
VII-3	25°01.94	81°18.80	Sparse uniform live bottom	21	8a
VII-4	25°01.94	81°21.80	Sparse uniform live bottom	24	8a
VII-5	25°01.94	81°24.80	Sparse uniform algae and *H. decipiens*	26	4a
6*	24°59.83	81°27.17	Sparse uniform algae and live bottom	28	8a
VII-6	25°01.94	81°27.80	Sparse uniform algae and live bottom	29	8a
4*	25°03.47	81°30.55	Dense uniform *H. decipiens*	33	3a
VII-7	25°01.94	81°30.80	Bare sand bottom	34	5a
VII-8	25°01.94	81°33.80	Sparse uniform live bottom	36	8a
VIII-1	25°17.02	81°27.22	Sparse *Thalassia*, *Halodule*, and live bottom	20	2b
VIII-2	25°17.02	81°30.22	Sparse uniform live bottom	32	8a
VIII-3	25°17.02	81°33.22	Sparse uniform *H. decipiens*	37	4a
VIII-4	25°17.02	81°36.22	Dense uniform live bottom	41	7a
VIII-5	25°17.02	81°39.22	Bare sand	42	5a
VIII-6	25°17.02	81°42.22	Sparse, patchy *H. decipiens*	44	4b
VIII-7	25°17.02	81°45.22	Sparse, patchy *H. decipiens*	48	4b
VIII-8	25°17.02	81°48.22	Dense, patchy *Syringodium*	49	2b
VIII-9	25°17.02	81°51.22	Dense, patchy *H. decipiens*	52	3b
VIII-10	25°17.02	81°54.22	Dense uniform *H. decipiens*	54	3a
VIII-11	25°17.02	82°07.62	Dense uniform *H. decipiens*	75	3a

Table 3.1. (Continued).

Station	Latitude	Longitude	Description	Depth (ft)	Classification
VIII-12	25°17.02	82°12.62	Sparse, patchy *H. decipiens*	84	4b
VIII-13	25°17.02	82°17.62	Bare, course sediment (algal nodules)	91	5a
VIII-14	25°17.02	82°22.62	Bare, course sediment (algal nodules)	93	5a
VIII-15	25°17.02	82°27.62	Bare, course sediment (algal nodules)	106	5a
VIII-16	25°17.02	82°32.62	Sparse uniform *H. decipiens*	116	4a
VIII-17	25°17.02	82°37.62	Sparse uniform *H. decipiens*	124	4a
VIII-18	25°17.02	82°41.19	Sparse uniform algal-covered bottom	129	4a
II-6	26°02.00	82°48.66	Sparse, patchy algae	128	4b
II-7	26°02.12	82°49.04	Sparse, patchy live bottom	129	8b
O[§]	26°17.82	82°58.91	Bare sand	126	5a
Σ[§]	26°18.33	82°56.04	Sparse, patchy live bottom	128	8b
▲[§]	25°09.01	82°33.10	Uniform *Caulerpa*, sparse *H. decipiens*	122	4b
XI-4	24°41.25	82°53.05	Coral reef	27	10
XI-5	24°41.25	82°52.05	Sand flat	65	5a
XI-6	24°41.25	82°51.05	Dense *Thalassia*	46	1a
XI-7	24°41.00	82°50.13	Sand flat	45	5a
XI-8	24°40.33	82°49.22	Silty clay bottom	42	5b
XI-9	24°40.15	82°48.27	Dense *Syringodium*	39	1a
XI-10	24°40.00	82°47.25	Coral reef	33	10
XI-11	24°40.00	82°46.15	Bare sand	85	5a

Note: The planned Transect IX was not sampled; instead, Transect II was extended into deeper water.

[*] Indicates a signature control station picked from the aerial imagery.
[§] Indicates stations added along the outer depth range.

a hybrid, though unique combination of the sparse uniform and dense uniform seagrass habitat classification.

In the middle and lower Keys there exist areas of primarily barren hard bottom with occasional solitary corals and gorgonids growing across them. These portions of the carbonate platform forming the Florida Keys have been aerially weathered and have solution features where sediments collect. Seagrasses appear continuously, but extremely sparsely across such habitats, however, they may form small, dense stands within the accumulated sediments in solution features. Within this habitat (12) such scattered dense stands are smaller and less uniformly distributed than the dense stands seen growing in inundated mangrove habitats of Florida Bay. Again, no density figure can be assigned to this type of unique seagrass habitat.

Table 3.2 presents density ranges for each habitat type mapped based on ground survey data. No H. engelmannii was seen anywhere within this study area. All deepwater seagrass beds were stands of H. decipiens. Density ranges for the offshore H. decipiens habitats are given in blades per m^2, while those of the soft-coral flats are given as percent cover. The scattered, coral-patch-reef designation (9) is not amenable to qualification, and organism coverage in the continuous, coral-reef classification (10) is 100%. Percent cover for dense and sparse nearshore seagrass beds are taken from the literature rather than this study (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985; Virnstein and Cairns, 1986).

Eighty-three stations were sampled by divers (Table 3.1), and 96 nmi (178 km) of transects were surveyed by diver and video tows (Table 3.3). Depths, habitat descriptions, and habitat classifications for all diver-sampled stations are given in Table 3.1. Table 3.4 shows the relative percent composition of each designated habitat on each diver/television transect surveyed.

The most abundant habitat types, in terms of area, seen within the Federally regulated shelf area were: 1) the dense and sparse stands of macroalgae and H. decipiens, and 2) the dense and sparse soft coral flats (Figure 3.2 and Table 3.5). Both these habitat types fit within the current Federal definition of live bottom; however, the hard and soft coral/sponge communities on the west Florida shelf are permanent features, while the macroalgae and H. decipiens stands are seasonal and may shift location from year to year.

3.2 GROWTH RATE

Table 3.6 presents the location, substrate type, and depth of the repetitively sampled H. decipiens growth-rate monitoring stations. Figure 2.3 (Section 2.3.1) shows the location of these stations. Table 3.7 presents the blades per m^2 and biomass at each sampling station on each survey.

Due to operational constraints during the major ground truth survey, only three of the seasonal growth-rate monitoring stations were resampled at that time. These were stations 16, 17, and 18 which were

Table 3.2. Density values for habitat classifications mapped.

Habitat Type	Classification Code	Density Range
Dense Nearshore Seagrass Beds	1a and b	200 to 2,000 blades/m^2* (71 to 100% cover)*
Sparse Nearshore Seagrass Beds	2a and b	41 to 199 blades/m^2* (30 to 70% cover)*
Dense Offshore <u>Halophila</u> and Algae Stands	3	1,000 to 4,000 blades/m^2
Sparse Offshore <u>Halophila</u> and Algae Stands	4	0 to 1,000 blades/m^2
Non-Vegetated Sand Bottom	5	N/A
Non-Vegetated Mud Bottom	6	N/A
Dense Soft Coral Flats	7a and b	17 to 54% cover
Sparse Soft Coral Flats	8a and b	5 to 16% cover
Scattered Coral Patch Reefs	9	N/A
Continuous Coral Reef	10	100% cover
Sparse Nearshore Seagrass Interspersed with Dense Patches	11	N/A
Hard Bottom Interspersed with Occasional Dense Patches of Seagrass	12	N/A

*Based on data collected in the Florida Big Bend Seagrass Habitat Study (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985).

Table 3.3. Location and length of diver and video survey transects.

	Beginning		End		Transect Length (nmi)	
Transect	Latitude	Longitude	Latitude	Longitude	Diver	Video
Ia	26°19.21	82°31.26	26°19.49	82°40.65	3.75	4.50
II	26°01.86	82°14.91	26°01.93	82°26.89	9.09	1.60
III	25°34.94	82°19.63	25°35.03	82°30.62	--	11.00
XIa*	24°24.09	82°55.71	24°42.12	82°53.95	0.80	1.20
XIb*	24°40.16	82°45.24	24°40.09	82°42.22	--	3.00
II	26°02.01	82°27.30	26°01.95	82°35.28	1.94	4.18
Ib	26°19.50	82°49.38	26°19.52	82°57.17	--	7.80
X	26°08.53	81°57.00	26°12.73	81°56.63	1.37	--
XII[§]	25°22.50	82°14.58	24°55.50	82°14.55	--	27.00
XIII[§]	25°09.10	82°14.31	25°09.01	82°33.10	2.26	16.53

*Transect XI runs across the waters within the Fort Jefferson National Monument Marine Preserve. Diver and video tows were replaced by a series of bounce dives within the National Monument jurisdiction.

[§] Transects added after the original study plan was laid out.

Table 3.4. Percent habitat composition of diver tow and video survey transects.

Habitat Type	Classification Code	Ia	IIa	III	XIa	XIb	IIb	Ib	X	XII	XIII
1. Dense Nearshore Seagrass											
Uniform	1a	--	--	--	--	--	--	--	--	--	--
Patchy	1b	--	--	--	--	--	--	--	--	--	--
2. Sparse Nearshore Seagrass											
Uniform	2a	--	--	--	--	--	--	--	--	--	--
Patchy	2b	--	--	--	--	--	--	--	--	--	--
3. Dense *Halophila* and Algae Stands											
Uniform	3a	--	--	--	--	--	--	--	--	--	--
Patchy	3b	0.75	14.71	22.83	11.90	32.08	7.92	--	--	10.43	1.42
4. Sparse Offshore *Halophila* and Algae Stands											
Uniform	4a	--	--	--	--	--	--	--	--	--	--
Patchy	4b	39.85	29.40	34.65	7.14	24.53	26.73	23.00	39.76	54.60	68.87
5. Non-Vegetated Sand Bottom	5	24.81	31.18	11.81	39.48	13.21	49.51	59.00	38.55	31.90	27.36
6. Non-Vegetated Mud Bottom	--	--	--	--	--	--	--	--	--	--	--
7. Dense Soft Coral Flats											
Uniform	7a	--	--	--	14.29	9.43	--	--	--	--	--
Patchy	7b	5.26	10.59	11.02	--	--	--	5.00	16.87	1.23	--
8. Sparse Soft Coral Flats											
Uniform	8a	--	--	--	--	--	--	--	--	--	--
Patchy	8b	29.32	14.12	19.69	--	20.75	15.89	13.00	4.82	1.84	2.36
9. Scattered Coral Patch Reefs	9	--	--	--	11.90	--	--	--	--	--	--
10. Continuous Coral Reef Flats	10	--	--	--	15.29	--	--	--	--	--	--
11. Sparse Seagrass with Dense Patches	11	--	--	--	--	--	--	--	--	--	--
12. Hard Bottom Interspersed with Occasional Dense Seagrass Patches	12	--	--	--	--	--	--	--	--	--	--

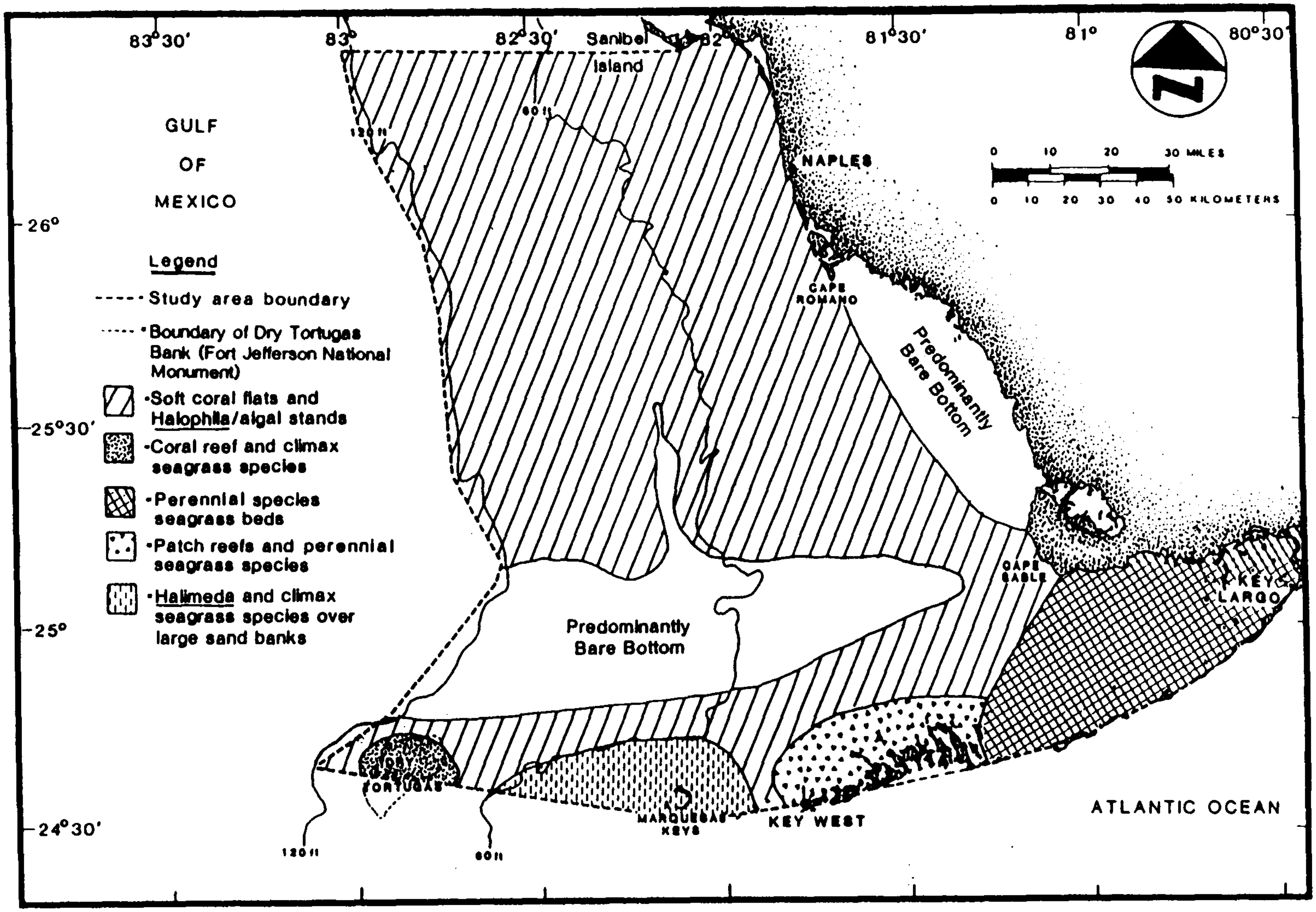

Figure 3.2. Generalized habitat map.

Table 3.5. Acreages of mapped habitats.

Habitat Type	Classification Code	Acreage Mapped From Aerial Imagery	Additional Acreage Estimated From Ground Survey	Total Estimated Acreage	Habitat Percent Coverage Within the Study Area
Dense Nearshore Seagrass Beds					
Uniform	1a	466,901	*	466,901	4.85
Patchy	1b	90,938	*	90,938	0.94
Sparse Nearshore Seagrass Beds					
Uniform	2a	41,534	*	41,534	0.43
Patchy	2b	498,199	*	498,199	5.17
Dense Offshore *Halophila* and Algae Stands					
Uniform	3a	§	*	0	0
Patchy	3b	832,035	323,519	1,155,554	12.00
Sparse Offshore *Halophila* and Algae Stands					
Uniform	4a	§	*	0	0
Patchy	4b	§	1,848,681	1,848,681	19.20
Non-Vegetated Sand Bottom	5	2,488,593	1,571,379	4,059,972	42.17
Non-Vegetated Mud Bottom	6	150,283	*	150,283	1.56
Dense Soft Coral Flats					
Uniform	7a	§	*	0	0
Patchy	7b	23,932	277,302	301,234	3.13
Sparse Soft Coral Flats					
Uniform	8a	§	*	0	0
Patchy	8b	§	600,821	600,821	6.24
Scattered Coral Patch Reefs	9	10,252	*	10,252	0.11
Continuous Coral Reef Flats	10	6,907	¶	6,907	0.07
Sparse Nearshore Seagrass with Dense Patches	11	309,243	*	309,243	3.21
Hard Bottom Interspersed with Occasional Dense Seagrass Patches	12	86,696	*	86,696	0.90
TOTALS		5,005,513	4,621,702	9,627,215	

*Habitat classification not seen on ground truthing survey.
§Habitat classification not seen on aerial imagery.
¶Habitat seen only at Fort Jefferson National Monument (Dry Tortugas).

Table 3.6. Location, substrate type, and depth of seasonal, growth-rate sampling stations.

Station	Latitude	Longitude	Description	Depth (ft)
1	26°01.77	81°55.47	Coarse sand	36
2	25°57.91	81°59.12	Live-Bottom (thin sand)	46
3	25°55.83	82°02.39	Live-Bottom (thin sand)	52
4	25°54.49	82°05.06	Coarse sand	57
5	25°50.53	82°10.01	Coarse sand	66
6	25°45.54	82°13.89	Coarse sand	74
7	25°43.03	82°17.52	Medium grain sand	80
8	25°39.03	82°22.00	Coarse sand	88
9	25°35.57	82°29.40	Medium grain sand	100
10	25°22.04	82°39.40	Coarse sand	122
11	25°21.53	82°14.97	Coarse sand	84
12	25°19.99	82°14.96	Coarse sand	83
13	25°18.02	82°14.98	Fine sand	84
14	25°13.99	82°14.97	Fine sand	87
15	25°10.00	82°14.98	Fine sand	87
16	25°00.00	82°14.97	Fine sand	80
17	25°09.00	82°14.57	Medium grain sand	86
18	25°08.40	82°16.03	Fine sand	89
19	25°07.46	82°15.53	Medium grain sand	87
20	25°33.00	82°23.02	Fine sand	97
21	25°39.02	82°18.01	Coarse sand	82
22	25°42.04	82°14.03	Coarse sand	75
23	25°49.98	82°08.01	Live-Bottom (thin sand)	63
24	25°50.06	82°04.99	Live-Bottom (thin sand)	57
25	25°53.03	82°01.01	Coarse sand	46
26	25°55.90	81°55.55	Live-Bottom (thin sand)	39
27	26°00.20	81°51.57	Coarse sand	28

Table 3.7. Blade count and biomass at the repetitive, growth-rate sampling stations.

	8-10 Jun 1988		5-8 Jul 1988		1-4 Aug 1988		29 Nov-1 Dec 1988		5-7 Jan 1989	
Station	Blades/m^2	Biomass mg/m^2	Blades/m^2	Biomass mg/m^2	Blades/m^2	Biomass mg/m^2	Blades/m^2	Biomass mg/m^2	Blades/m^2	Biomass mg/m^2
1	447	58.38	961	154.12	612	64.37	0	0.00	0	0.00
2	0	0.00	22	0.90	107	7.49	0	0.00	0	0.00
3	85	6.89	330	43.38	300	35.31	0	0.00	0	0.00
4	0	0.00	978	119.88	1,130	109.39	0	0.00	0	0.00
5	19	1.66	574	78.18	1,261	156.28	0	0.00	0	0.00
6	131	12.79	521	61.99	787	92.97	0	0.00	0	0.00
7	364	40.51	1,873	219.28	1,168	123.75	0	0.00	0	0.00
8	3	0.57	159	18.77	581	63.19	0	0.00	0	0.00
9	96	9.19	376	41.49	2,679	411.83	0	0.00	0	0.00
10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
11	22	2.37	238	22.82	0	0.00	0	14.47	0	0.00
12	0	0.00	124	12.68	2,231	270.15	105	26.78	0	0.00
13	107	12.40	11	0.56	1,485	146.75	125	28.66	0	0.00
14	63	6.94	374	35.38	990	96.87	54	17.13	0	0.00
15	79	6.65	520	88.37	1,117	213.92	147	48.25	0	0.00
16	56	5.72	1,549	177.34	2,654	334.64	*	*	0	0.00
17	0	0.00	2,169	408.98	3,872	1,021.29	171	42.13	0	0.00
18	9	0.81	608	89.84	3,376	493.48	54	18.39	0	0.00
19	*	*	282	23.18	1,360	317.00	0	0.00	0	0.00
20	56	4.98	0	0.00	985	93.41	*	*	0	0.00
21	13	1.34	100	6.14	773	39.53	*	*	0	0.00
22	431	45.11	4,202	495.30	1,096	91.37	*	*	0	0.00
23	409	49.25	476	55.75	1,383	147.63	*	*	0	0.00
24	308	47.11	694	90.45	332	30.97	*	*	0	0.00
25	137	12.23	194	22.10	92	13.43	*	*	0	0.00
26	173	24.75	323	39.86	91	10.69	*	*	0	0.00
27	0	0.00	268	23.18	32	2.70	*	*	0	0.00

*Sampling at these stations on the dates given was prevented by bad weather.

sampled in association with Transects XII and XIII (Figure 2.4). A total of 32 H. decipiens stations were sampled during the ground truthing survey in a variety of depths across the study area (Figure 2.4 and Table 3.8).

Figure 3.3 shows the mean shelf-wide biomass, mean biomass at stations 16, 17, and 18, and the maximum biomass encountered in H. decipiens beds during each of the six surveys. Stations 16, 17, and 18 are plotted as a stand-alone data set because they are the only stations actually sampled on all six surveys. The shelf-wide and maximum biomass figures for the September survey reflect the biomass values from the stations listed in Table 3.8.

Halophila decipiens growth had just begun at the time of the first sampling in early June (Figure 3.3 and Table 3.7). Most H. decipiens growth occurred between June and August (Figure 3.3). Increases in biomass seen in the first two months of the growing season reflected increases in the number of blades sprouting. Between August and late September, producion in the H. decipiens beds leveled off (Figure 3.3). Increases in biomass during this period represented increases in the size of the individual leaves (Figure 3.4).

Throughout the growing season, leaves in the 0- to 5-mm and 6- to 10-mm size classes were numerous. Leaves in the larger size-class ranges showed a steady increase throughout the growing season and surpassed the smaller ranges in the next-to-last survey (Figure 3.4). When leaves in the 11-mm and higher size-class range began to outnumber smaller leaves in these offshore H. decipiens beds, the growing season had ended and decline had begun. By late November and early December, only remnants of what were once the most extensive H. decipiens stands could be found (Figure 3.3).

During the final short survey (5-7 January 1989), no H. decipiens was seen at any of the sampled stations. Macroalgae were scarce, and all sampled stations appeared to be in a quiescent winter phase.

Table 3.8. Blade counts and biomass of *Halophila decipiens* sampled during the 20 September to 4 October 1988 ground truth survey.

Station	Date Sampled	Depth (ft)	Blades/m^2	Biomass (mg/m^2)
I-4	20 Sep	70	1,697	254.22
I-5	20 Sep	75	2,106	285.86
II-1	21 Sep	48	2,461	267.58
II-3	21 Sep	58	24	2.07
II-4	21 Sep	59	192	20.24
II-5	21 Sep	66	295	23.00
III-5	22 Sep	78	201	21.72
III-7	22 Sep	86	2,321	332.95
III-9	22 Sep	92	2,244	371.40
IV-7	27 Sep	77	645	88.56
V-2	27 Sep	40	286	32.81
VI-3	25 Sep	56	896	154.91
VI-5	25 Sep	42	1,745	196.39
VI-6	25 Sep	42	810	87.66
VII-5	28 Sep	26	39	3.42
G-4*	28 Sep	33	6,583	678.19
VII-8	28 Sep	36	436	34.62
VIII-3	23 Sep	37	178	11.22
VIII-6	23 Sep	44	306	26.86
VIII-7	23 Sep	48	463	54.61
VIII-9	23 Sep	52	667	80.68
VIII-10	23 Sep	54	6,113	1,201.54
VIII-11	1 Oct	75	1,515	226.59
VIII-12	1 Oct	84	200	29.92
VIII-16	1 Oct	116	587	87.82
VIII-17	1 Oct	124	141	21.09
XI-5	24 Sep	65	121	10.69
XI-6	24 Sep	45	296	22.12
16[§]	29 Sep	86	3,316	884.27
17[§]	28 Sep	89	2,484	333.88
18[§]	29 Sep	87	2,103	327.74
▲[¶]	30 Sep	122	231	34.56

*Off transect station selected from aerial imagery.

[§] Seasonal sampling stations sampled on September-October survey.

[¶] Off transect station selected by depth.

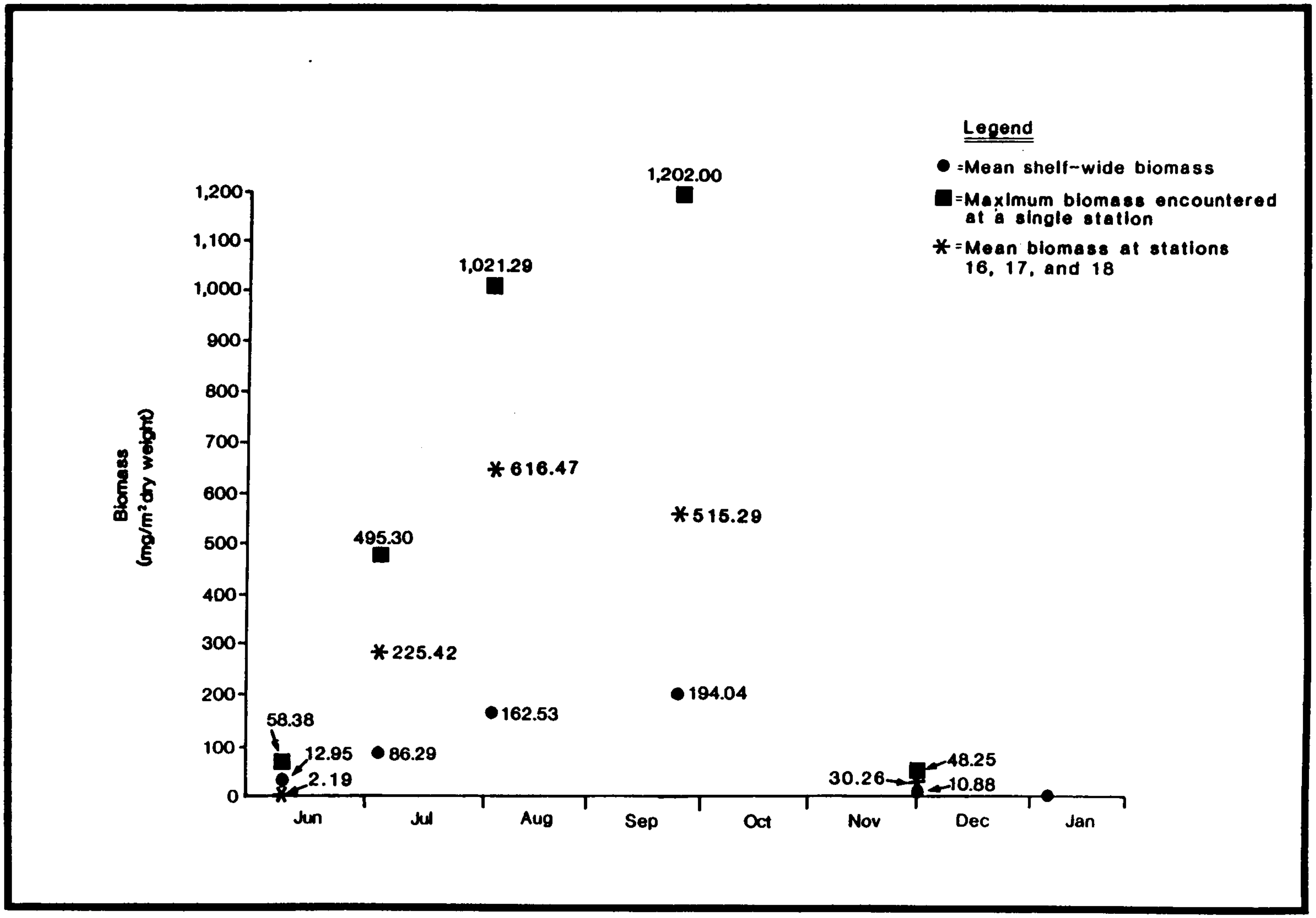

Figure 3.3. Mean Halophila decipiens biomass across the southwest Florida continental shelf over the 1988 growing season.

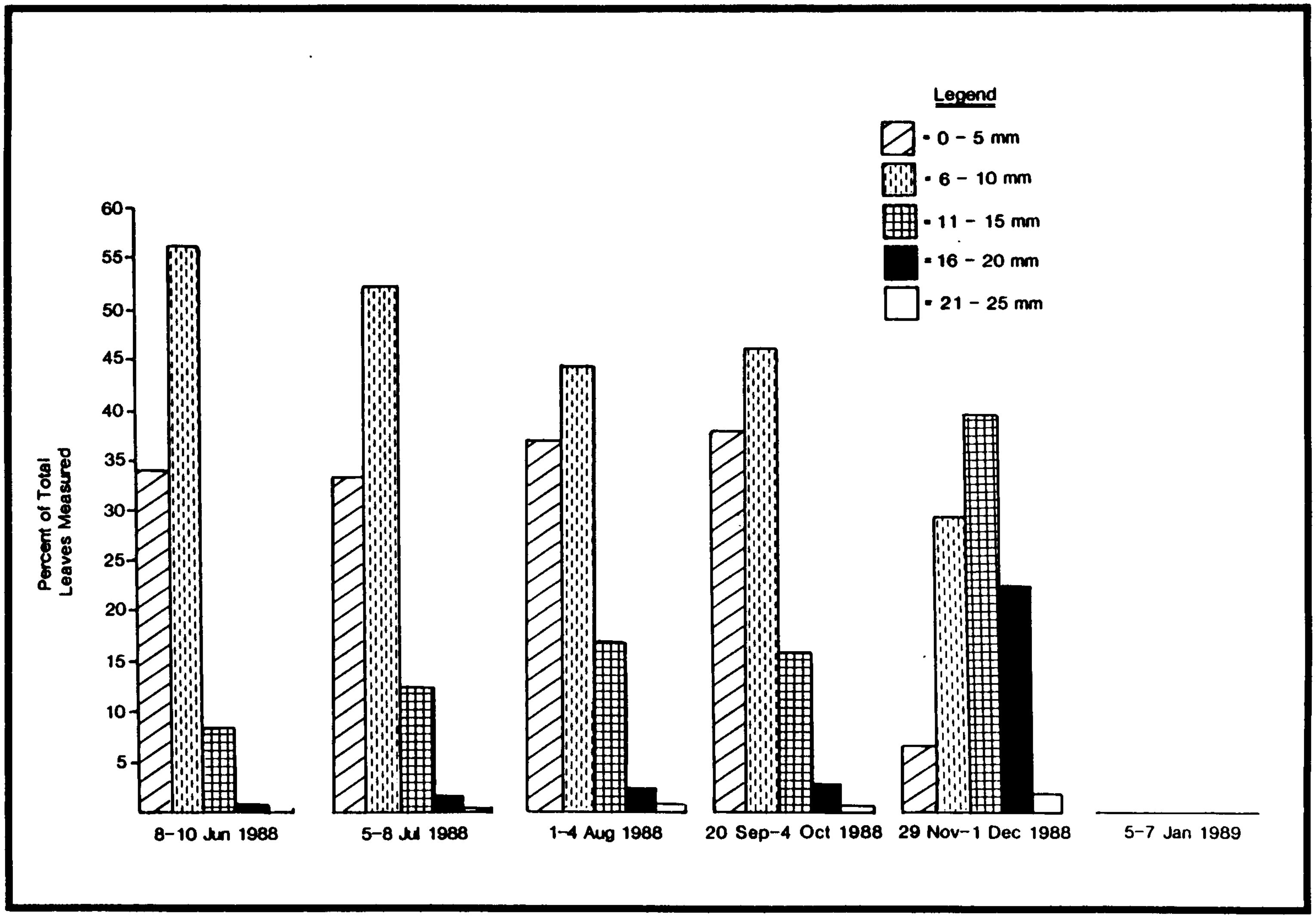

Figure 3.4. Sample composition by blade length over the 1988 sampling period.

4.0 DISCUSSION

4.1 HABITAT DISTRIBUTION

4.1.1 Geomorphic Units of the Study Area

Habitat distribution in the Southwest Florida Nearshore Benthic Habitat Study area is the product of varying geological and physical conditions. The southwest Florida nearshore continental shelf is geomorphically more complex than the previously mapped northwest shelf area of the Florida Big Bend. Essential geomorphic units in this study area consist of:

1) The inner western Florida continental shelf as defined by the area from Sanibel Island (26°30'N) to Cape Sable (25°10'N) and extending from shore to a depth of approximately 130 ft (39.6 m);

2) Florida Bay, a broad area of water typically <9 ft (3 m) deep which is subdivided by mud banks and separated from the South Atlantic Ocean by the Upper Florida Keys;

3) The north side of the Middle and Lower Florida Keys which form the southern boundary of the study area; and

4) The banks and reefs along the Florida Straits of which Marquesas Keys and the Dry Tortugas Banks are the most prominent. Tortugas Bank forms the western terminus of the study area.

Much of the inner shelf north of 25°N is covered by a thin layer of mobile sand, with small-scale outcrops of exposed hard bottom. Sediments in this area consist of: 1) a nearshore zone of predominantly detrital quartz sands deposited from coastal rivers, beaches, and older coastal plain sediments; 2) a zone of transitional quartz/carbonate sediments lying between the 27- to 60-ft (8.2- to 18.2-m) depth contours; and 3) a carbonate sediment sheet extending into deeper water (Continental Shelf Associates, Inc., 1987a).

Florida Bay sediments are composed primarily of limestone muds, with high contributions of organic matter and shell. The surficial sediments along the Florida Keys are biogenic in origin, composed mainly of oolitic sand and algal flakes. Similar sediments occur on the banks forming the southern terminus of the study area (Environmental Science and Engineering, Inc. et al., 1987).

Of particular importance to this discussion of habitat distribution patterns is an area of silty sand and sandy silt which extends from the mouth of Florida Bay westward to the Dry Tortugas Bank, roughly paralleling the 25°N latitude line. This sediment barrier effectively divides the northern, inner-shelf portion of the study area (characterized by low-relief, hard bottom, H. decipiens and algal stands) from the southern portion (characterized by the reef banks and islands) (Figure 4.1).

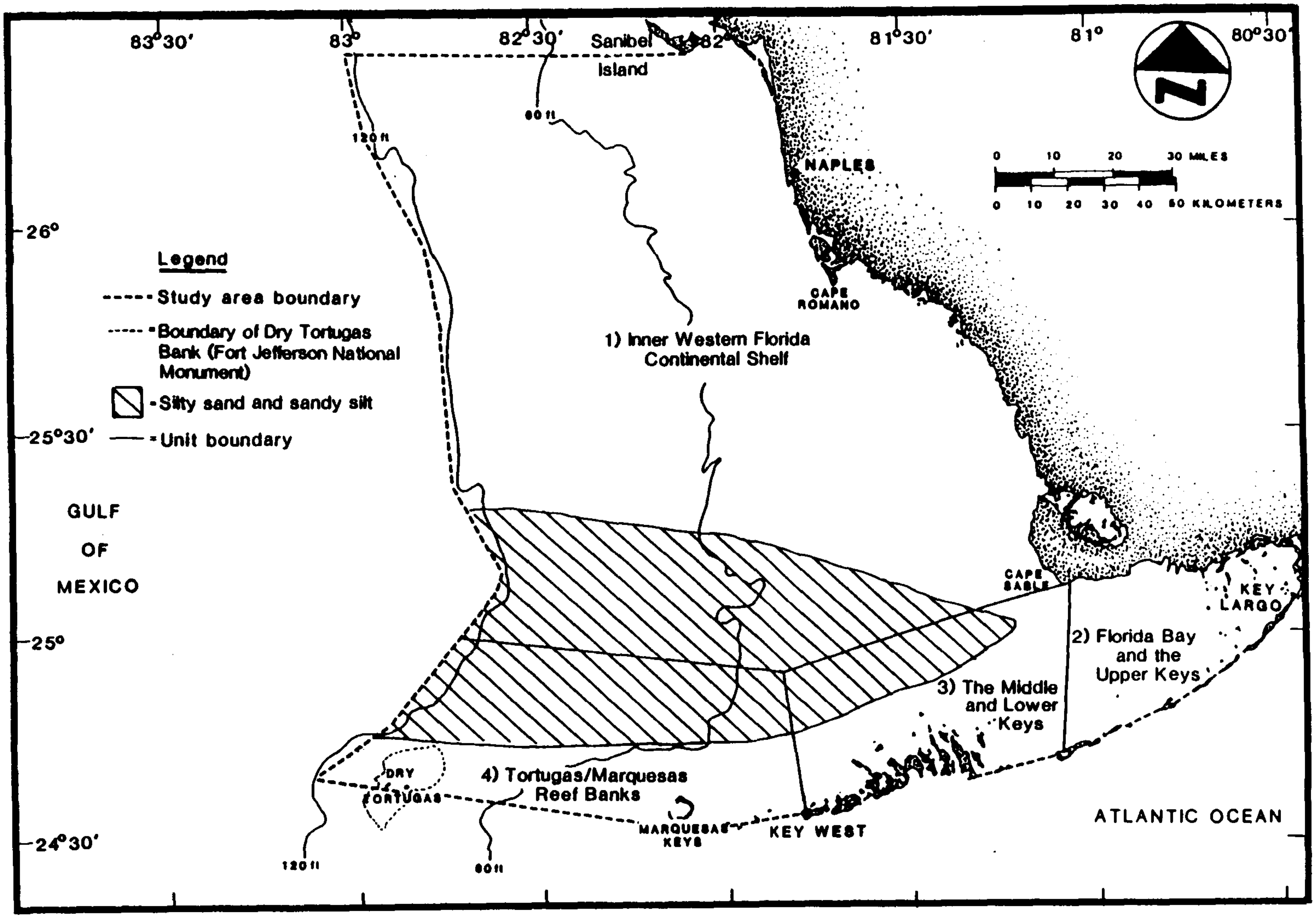

Figure 4.1. Geomorphic units of the study area.

The area indicated as silty sand and sandy silt in Figure 4.1 corresponds almost exactly to the "Tortugas shrimping grounds" (J. Zieman, 1989, personal communication, University of Virginia). Economically, this area of predominately bare bottom may be the most valuable habitat surveyed in terms of immediate harvest.

4.1.2 Habitats of the Inner Shelf

Extensive coastline and nearshore seagrass beds, such as those occurring in the Florida Big Bend area, are not seen off southwest Florida between Sanibel Island and the mouth of Florida Bay. There are sporadic outcrops of hard bottom paralleling the shoreline at approximately the quartz sand/carbonate sand interface in 20 to 60 ft (6.1 to 18.2 m) of water. Halophila decipiens grows in and around these hard-bottom outcrops, but never reaches the densities seen farther offshore.

Most of the inner shelf north of 25°N consists of a mosaic of carbonate sand, hard-bottom outcrops, and thin carbonate sand over hard bottom. These patterns have been previously reported (Continental Shelf Associates, Inc., 1985, 1987a; Environmental Science and Engineering, Inc. et. al., 1987). Plate 1 (a side-scan sonar mosaic) shows a typical area within 70- to 80-ft (21.3- to 24.3-m) depth contours on a portion of the inner west Florida shelf. In this mosaic, the patterns indicate a wave-sorted area of coarse- and fine-sediment ribbons (Belderson et al., 1972). Lighter portions indicate thicker accumulations of sand and silty sand, whereas the darker bands indicate coarse sediment and algal rubble.

Sessile epibiota (e.g., gorgonians, hard corals, and sponges) are frequently seen protruding through the sand veneer in both habitat types. Protruding epibiota indicate that considerable sand movement occurs in these areas, since such organisms must settle and begin their lives on exposed hard bottom. Danek and Lewbel (1986) suggest that wave action is the most important influence on sediment movement within this study area.

Major sessile invertebrate groups in the hard-bottom habitats described as "dense" included gorgonians (e.g., Eunicea spp., Muricea spp., Plexaurella spp., and Pseudopterogorgia spp.) and larger sponges (e.g., the loggerhead sponge Speciospongia vesparia, the vase sponge Ircinia campana, and various species of finger sponges). Scleractinians (hard corals) were also present, but these were smaller and less noticeable than the larger and more abundant gorgonians and sponges.

The macroalgal component of the southwest Florida H. decipiens and macroalgal stands is considerably less than that noted in the Big Bend area. Within the offshore seagrass beds between 33 and 66 ft (10.1 and 20.1 m) in the Big Bend area, macroalgae accounted for an average of 21% of the plant density (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985). Within the same type of communities along the southwest Florida shelf, macroalgae accounted for <3% of the plant density observed in the quantitative seagrass stations sampled. The algal species growing in association with H. decipiens were generally

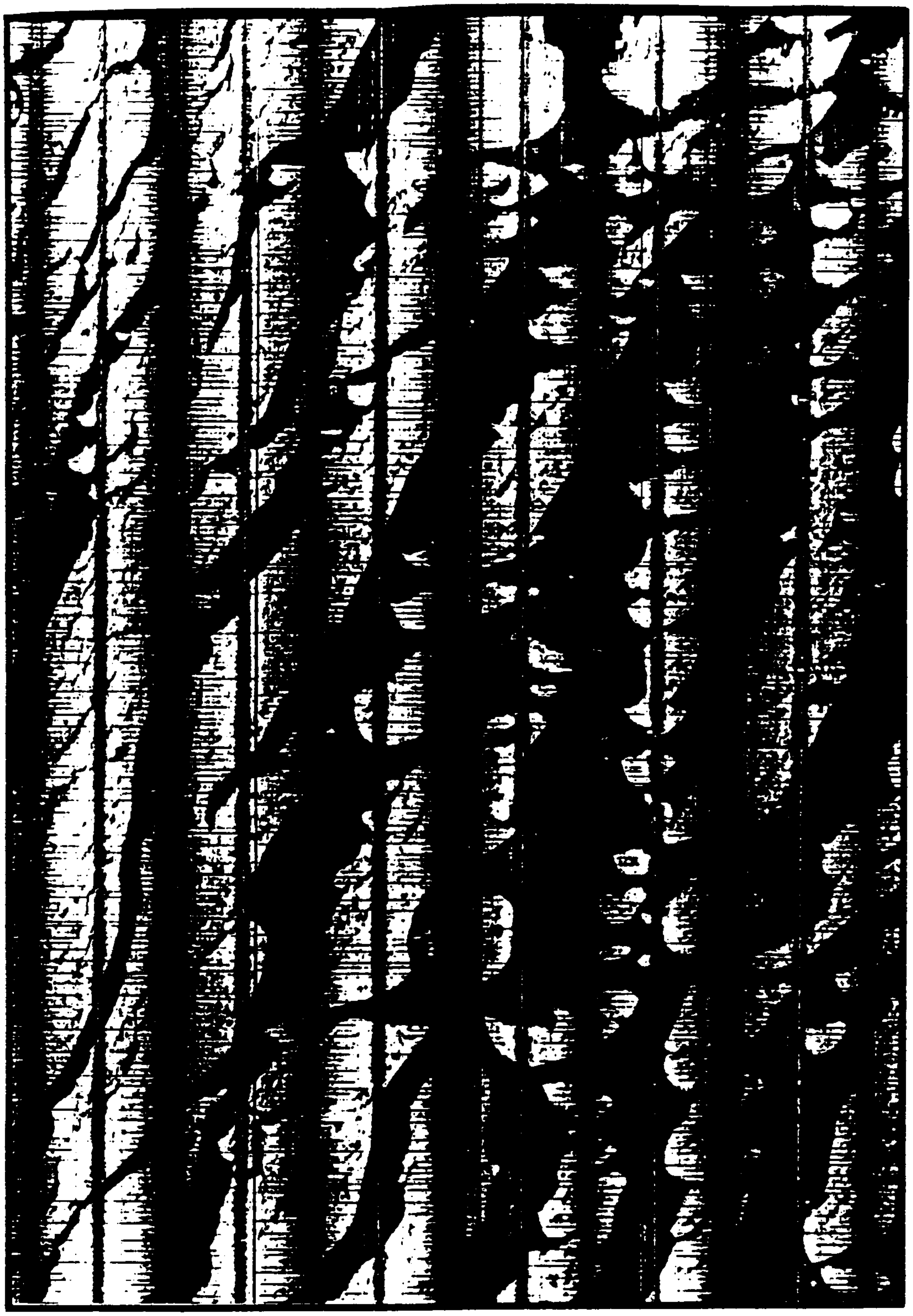

Plate 1. Side-scan sonar mosaic of a typical area of the southwest Florida continental shelf at approximately the 80-ft (24-m) bathymetric contour. Light areas indicate sand and silty sand, dark areas indicate coarse sediment and algal rubble.

the same in both areas, with Caulerpa sertularioides being the most abundant, followed by C. prolifera and C. mexicana. Beginning at about the 80-ft (24.4-m) contour, a deepwater, thin-bladed phenotype of C. prolifera began to appear. This growth form of C. prolifera became more abundant with depth and eventually replaced H. decipiens completely in stations sampled below 122 ft (37.2 m).

No H. engelmannii was seen anywhere along the southwest Florida continental shelf during the 1988 sampling. This species was abundant along Florida's northwest shelf (the Big Bend area) in 1984 and 1985, forming monotypic stands in the 40- to 55-ft (12.2- to 16.8-m) depth ranges (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985; Continental Shelf Associates, Inc., 1988). Halophila engelmannii has been reported in depths of 295 ft (90 m) off Dry Tortugas (Zieman, 1982), and its absence from what appeared to be prime habitat is extremely interesting. Unfortunately, further investigations of this phenomenon were beyond the scope of this contract.

At the peak of its growing season, H. decipiens is virtually ubiquitous across the southwest Florida continental shelf from a depth of approximately 20 ft (6.1 m) out to approximately 90 ft (27.4 m). Halophila decipiens was seen to a depth of 122 ft (37.2 m) during the September 1988 survey; deeper than approximately 90 ft (27.4 m), it was less uniformly distributed, gradually thinning out until it disappeared completely. Halophila decipiens grew most densely in areas of firmly packed sand and silty sand. In areas of coarser substrate, it grew sparsely; and in areas of protruding hard-bottom biota or where sand thinly covered hard bottom, H. decipiens growth was not abundant. In these areas, macroalgal species made a larger contribution to the observed floral density.

Data collected in this study showed a mean biomass of 194.0 mg/m^2 for H. decipiens in September 1988 as compared to the 160.9 mg/m^2 recorded from the Florida Big Bend area in October of 1984 (Continental Shelf Associates, Inc., 1987b). Extrapolating from the southwest Florida shelf mean yielded an estimated shelf-wide standing crop for H. decipiens of 2,600 tons (2,359 metric tons) in September of 1988.

In its optimum habitat, H. decipiens is considerably more abundant on the southwest Florida shelf than in the Big Bend area. Maximum blade counts seen in sample stations from the Big Bend area were from 1,627 to 2,029 blades per m^2. Along the inner shelf off southwest Florida, the most dense stations sampled showed blade counts ranging from 6,113 to 6,583 blades per m^2.

4.1.3 Habitats of Florida Bay

Florida Bay is a triangular, tropical lagoon/bay occupying a shallow, trough between the exposed barrier reefs of the Florida Keys and a series of mangrove-lined bays and sounds at the southern tip of the Florida peninsula. The Bay covers approximately 550,000 ac (222,585 ha) and its bottom is almost completely carpeted with seagrass and macroalgal communities. Thalassia testudinum is the most abundant seagrass seen, but S. filiforme, H. wrightii, H. decipiens, and H.

engelmannii are also present (Zieman, 1982; Zieman et al., 1989). Figure 4.2 illustrates the relative sizes of these seagrass species. Thalassia testudinum is considered to be the climax species in the succession of soft-bottom macrophyte communities in south Florida and the Caribbean (Zieman, 1982).

In 1985, National Park Service personnel based in Everglades National Park produced a map of benthic communities within the portion of Florida Bay administered by the Park Service. This map was based on 1965 aerial imagery, supplemented with extensive ground truthing conducted in the early 1980s. Benthic communities were divided into nine categories based on their sessile biota (Table 4.1). At that time, communities dominated by T. testudinum (or those in which T. testudinum made a major contribution) covered over 73% or 321,000 ac (129,909 ha) within the National Park boundary.

Zieman et al. (1989) discuss seven benthic community types within Florida Bay, based on vegetative patterns. These were:

1) The Northeast community, characterized by sparse Thalassia and Halodule growth in the basins and sounds, and moderately dense Thalassia growth on the banks;

2) The East-Central community, dominated by sparse, patchy Thalassia throughout the basins and moderate to dense Thalassia along the banks;

3) The Interior community, in the Central Bay, dominated by dense, monospecific stands of Thalassia;

4) The Mainland community, in the western part of the run-off zone, dominated by dense monospecific stands of Thalassia similar to those of the Interior community, but with interspersed dense stands of Halodule and occasionally, in areas of maximum freshwater intrusion, Ruppia maritima;

5) The Gulf community of the Western Bay, with high density Thalassia stands interspersed with Syringodium and Halodule stands. Syringodium begins to dominate in the deeper areas within this community;

6) The Atlantic community, along the northern side of the Florida Keys in areas heavily influenced by tidal flushing, characterized by sparse Thalassia stands in deeper water and dense Thalassia on the banks. Dense stands of Syringodium occur in deeper areas of the tidal channels and there are occasional outcrops of hard-bottom communities; and

7) The Conchie Channel community, a deep, highly turbid tidal channel running just south of Cape Sable and draining the area south of Flamingo. This area is imaged very poorly in our aerial data and is characterized by

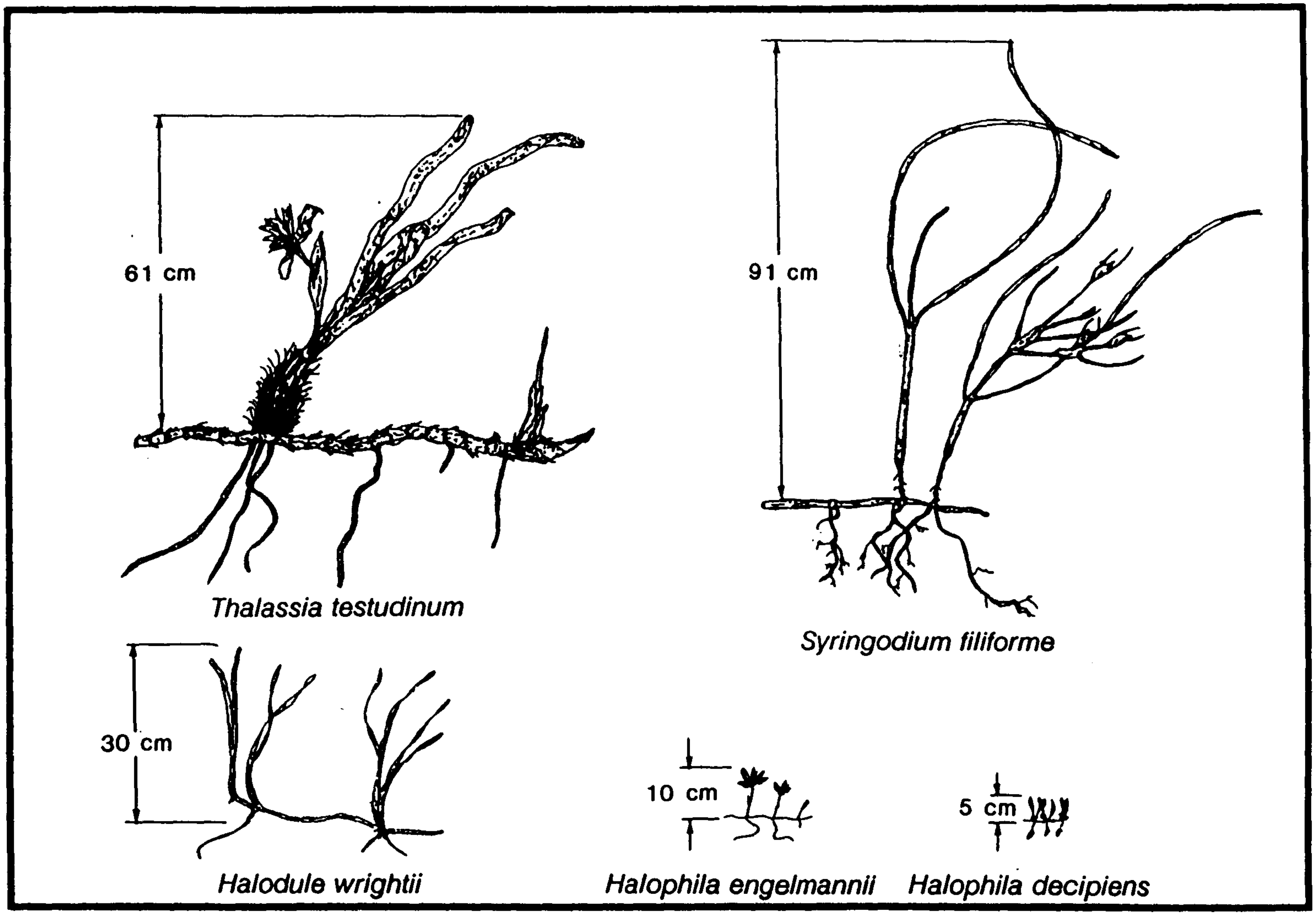

Figure 4.2. Relative sizes of the five species of seagrass seen in Florida.

Table 4.1. Florida Bay benthic communities within Everglades National Park (Adapted from: National Park Service, 1985).

Community	Acreage	Percent of Florida Bay
Mixed seagrass community of _Thalassia testudinum_, _Syringodium filiforme_, and _Halodule wrightii_	22,513	5.21
Thalassia testudinum dominated communities	98,838	22.89
Halodule wrightii dominated communities	1,647	0.38
Algal communities dominated by _Batophora_, _Acetabularia_, _Laurencia_, and _Caulerpa_ spp.	59,174	13.69
Calcareous algae and live-bottom communities	55,459	12.83
Mixed _Thalassia testudinum_ and _Syringodium filiforme_ communities	38,857	8.99
Mixed _Thalassia testudinum_ and _Halodule wrightii_ communities	80,559	18.64
Very sparse _Thalassia testudinum_ communities	56,719	13.12
Mixed _Thalassia testudinum_, coral, and algal community	23,288	5.39

widely scattered and sparse stands of Thalassia and Halodule. The bottom is hard-packed mud or muddy shell hash, with occasional outcroppings of hard bottom.

Although the habitat classification units used in this study do not correspond directly to those of the National Park Service (1985) and Zieman et al. (1989), review of the atlas (Volume II) maps herein covering the Florida Bay portion of the study area indicate essentially the same patterns relative to density and patchiness of the seagrass habitats mapped.

Hard-bottom communities such as soft-coral flats or scattered, coral patch reefs are rare within Florida Bay proper. Schmidt (1979) recognized a Thalassia-Porites community within the Atlantic community as described by Zieman et al. (1989), but this community only appeared on the nearshore side on the Florida Keys. Zieman et al. (1989) found local areas of hard bottom and patch reef communities in middle basins of their Gulf community classification, but again these areas are on the far western end of Florida Bay where it merges with the Gulf of Mexico.

Following the aerial overflights of October 1987, a massive die off of climax seagrass beds began in Florida Bay. Thalassia beds there are still dying and being replaced by Halodule (M. Robblee, 1989, personal communication, Everglades National Park). To date, over 4,000 ac (1,619 ha) of Thalassia beds have been destroyed. This seagrass die off, discussed at length in Appendix B, is continuing to make major modifications to the community structure and productivity of Florida Bay. All regulatory agencies having an interest in the eastern Gulf of Mexico should continue to monitor this situation closely.

4.1.4 Habitats of the Middle and Lower Florida Keys

The Florida Keys are a series of coral islands built on the ancient reefs and sand shoals of 125,000 years ago. The interplay of topography and sea-level rise explains much in terms of the observed distribution of habitats. The higher ridge of the Key Largo limestones separates the waters of Florida Bay from the Atlantic Ocean, forming the series of lagoons and enclosed basins previously discussed. Southwest of Conch Key, and northeast of Big Pine Key, in the Middle Keys, the large tidal flux in and out of Gulf and Atlantic waters through tidal channels and passes is a major environmental feature. Both seagrass and hard-bottom communities on the north side of the Middle Keys are sparse and patchily distributed.

Sedimentologically, the Lower Keys are composed of oolitic limestone, rather than the coralline limestone seen in the Upper Keys. The Lower Keys are also oriented in a north-south rather than east-west direction, leading to the suggestion that these islands may represent preserved, tidal-bar deposits (Hoffmeister and Multer, 1968).

Seagrass communities in the Lower Keys continue to be dominated by Thalassia and Syringodium, ranging from sparse to dense under specific environmental conditions. Within areas showing sparse to medium density seagrass coverage in the aerial imagery, macroalgae make a considerably greater contribution to the observed image densities than in the basins of the Upper Keys or in that portion of the study area to the north of Cape Sable. This is due to the greater exposure of bare rock and thinner sediments.

On the north side of the Lower Florida Keys, scattered, coral patch reefs (habitat classification 9) commonly occur. These habitats generally show larger, head-forming coral species (e.g., Montastrea annularis, and species of Diploria and Colpophyllia), surrounded by areas of lower relief, soft and hard coral habitats in which Siderastrea siderea, Solenastrea sp., and Dichocoenia stokesii are the most common hard-coral species.

Coral/gorgonian habitats associated with patch reef development on the northern side of the Florida Keys are distinct from the soft-coral flats (habitat classifications 7 and 8) applied to low-relief areas of hard bottom on Florida's inner shelf north of Cape Sable. In the Keys, these areas have a much higher percentage of hard corals relative to gorgonians. They also have a generally higher, more varied relief, and rarely, if ever, show signs of inundation by neighboring sand sheets. Along the northern side of the Lower Keys, there is a more or less continuous band of these scattered, coral patch reefs, located approximately 4 nmi (7 km) from shore. This band runs from Key West northeastward past Big Pine Key. At that point, this band becomes less distinct due to changing bottom topography, the widening of the tidal channels between the Middle Keys, and the merging of sediments with those of Florida Bay.

North of this patch reef zone, the bottom drops off rapidly into the area of silty sands and lime muds characteristic of the substrate off the mouth of Florida Bay (Figure 4.1). Ground truth transects IV and V were run across these habitats (Figure 2.2), revealing a narrow H. decipiens fringe area offshore of the patch reef community. At a depth of approximately 40 ft (12 m), all seagrass disappears and the bottom is a uniform silty mud.

4.1.5 Habitats of the Marquesas and Dry Tortugas Banks

Westward from Key West and separated from the Keys by the narrow North West Channel is a broad shallow bank or series of flats and shoals comprised of the Boca Grand Bank, the Marquesas, and the Quicksands. Patch reef development on the north side of these banks is rather poorly defined. Ground truth transects V and VI ran through this area (Figure 2.2).

Transect V, running slightly to the west of the Marquesas, showed all stations in <40 ft (12.2 m) of water to be typical "off bank" or back reef type communities characterized by sparse hard-coral and gorgonian growth. These stations did show a thin sand veneer in the grooves between hard-bottom habitats where sparse H. decipiens stands were present.

Transect VI was run at the extreme western end of the Quicksands. Stations in depths >40 ft (12.2 m) showed varying concentrations of H. decipiens while those shallower than 30 ft (9.1 m) showed bare, current-swept sand. Previous researchers have reported the Quicksands area as an extensive, current-swept sand flat where sand waves as high as 9 ft (2.7 m) have been seen (Shinn et al., 1982; Hudson, 1985; Shinn et al., 1989). The aerial imagery collected during this study substantiates this. The shifting nature of these sands has prevented development of extensive patch, or continuous coral-reef habitats in this area, but allowed major growths of the carbonate-sand-producing alga Halimeda sp. (Hudson, 1985).

With the exception of the Rebecca Shoal, no reef development was seen between the Quicksands and Dry Tortugas. Depth throughout this passage was approximately 80 ft (24.4 m) and the bottom was a current-swept sand. Dives and television tows made as part of Transect XI revealed sparse patches of H. decipiens and C. prolifera growing throughout this area, but neither species formed the continuous meadows seen at similar depths to the north of Cape Sable.

Reef development around the outer edge of the Dry Tortugas bank is luxuriant, forming an atoll-like rim, with several small islands within the atoll basin (Shinn et al., 1989). Transect XI ran from the northwest toward the southeast, directly across Dry Tortugas through the waters of Fort Jefferson National Monument Marine Preserve (Figure 2.2). The transect was begun approximately two miles to the northwest of the bank in 120 ft (36.6 m) of water. In this area, the bottom was a uniform, fine sand with occasional patches of coarse algal rubble. Little seagrass or algae was present, but the area showed considerable bioturbation. The reef slope began at 100 ft (30.5 m) and rose rapidly to a depth of 45 ft (13.7 m) where it leveled out. Reef community zones in the Keys and at Dry Tortugas have been described extensively (Dustan and Halas, 1987; Jaap et al., 1989; Shinn et al., 1989). Transect XI showed a progression of coral habitats from forereef to reef crest to back reef zone. For mapping purposes, these are all grouped into the continuous, coral-reef classification (10). After the diver and television portions of Transect XI were completed, a series of eight bounce dives were made across the crest of the bank. Quantitative photographs at these stations were later evaluated in developing the final habitat maps.

Utilizing color aerial photography provided by NASA, Gary E. Davis of the National Park Service constructed a very detailed habitat map for the Fort Jefferson National Monument in 1976 (Davis, 1979). Review of this map showed minimal change in habitat distributional patterns within the area of Fort Jefferson National Monument over the past 11 years. Thalassia and Halimeda dominated the seagrass and algal stands seen within the atoll ring. Although some H. decipiens was present in these stands, it was a minor contributor to seagrass densities.

4.2 SEASONALITY AND DEPTH RANGE OF HALOPHILA DECIPIENS

Data collected in this study indicate a growing season extending from late May through early October for H. decipiens on the southwest Florida shelf. Biomass, increasing rapidly in the deep seagrass beds throughout June and July, begins to level off in August and peaks in September. Leaf lengths within the sampled populations show a pattern of continued new blade emergence and older blade growth throughout June, July, August, and September; but as the September growing-season climax approaches, the percentage of larger, older leaves in individual samples increases.

No flowering in the *H. decipiens* meadows was observed during this study; however flowering was observed in the *H. decipiens* beds within the Big Bend study area in late August/early September of 1985 (Continental Shelf Associates, Inc., 1988). Flowering was also reported in late August and early September of 1986 and 1987 from *H. decipiens* beds off Anclote Key, on Florida's west coast just north of Tarpon Springs (Dawes et al., 1989). It is assumed that the *H. decipiens* seagrass meadows of the South Florida Nearshore Benthic Habitat Study area flower in late August and early September and that this event was missed during this study because of the timing of the sampling efforts.

Based on this study, and previous studies conducted in the Big Bend area (Thompson et al., 1989), it appears that late May and early June mark the initiation of the *H. decipiens* growth season shelf-wide off west Florida. It is also fairly clear from the collected data as well as previously published studies that the peak of the seagrass growing season for all seagrass species occurs between July and August along this coastline (Zieman, 1982; Iverson and Bittaker, 1986). Much less well-defined is the date when *H. decipiens* beds completely disappear.

In nine samples of a five year study off Anclote Key, *H. decipiens* was seen only from July through September (Dawes et al., 1989). Examples of *H. decipiens* and *H. engelmannii* stands were seen in the Big Bend area during a February 1985 survey (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985). *Halophila decipiens* contributed significantly to biotic cover of Station 51 of the Southwest Florida Regional Biological Communities Survey in December of 1982, but was not present during the 29 May to 8 June 1983 survey of that same study. Stations 17, 18, and 19 of the seasonally sampled station set from this study had been sampled previously by CSA in August of 1987 (Continental Shelf Associates, Inc., 1988). At that time, *H. decipiens* was present at these three stations, but it had completely disappeared by November of 1987.

Light, temperature, and wave action determine how long *H. decipiens* beds persist into the winter months after the growing season has peaked. As the waters off west Florida turn cooler and the days grow shorter in late fall and early winter, the *H. decipiens* meadows begin to deteriorate. Data from this study indicate that new growth, in the form of new blades, declines after August and virtually stops after October. The older leaves and root systems apparently begin to deteriorate in October. There is an increased incidence of blanching, or loss of chlorophyll from leaves still attached to the rhizome system, and the rhizomes themselves appear to begin to break up, becoming less firmly rooted in the substrate. Protein, lipid, and soluble carbohydrate ratios within the plant tissue may begin to shift as the growth season ends.

In their weakened, post-growth-peak phase, the offshore *H. decipiens* seagrass beds are easily uprooted and washed away by wave action and currents. The 1984-85 winter in the Florida Big Bend area was unusually warm and calm, allowing *Halophila* beds to remain present, at least in deep water, through almost the entire year (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985). In September of 1985, Hurricane Elena entered the Florida Big Bend area and completely obliterated all *Halophila* spp. growth for that growing season (Continental Shelf Associates, Inc., 1988; Thompson et al., 1989). Both *Halophila* species were again present in approximately their pre-hurricane densities during a follow-up survey in August of 1986 (Continental Shelf Associates, Inc., 1987b).

Off southwest Florida, the 1987 growing season terminated early due to the passage of Hurricane Emily through the southern end of the study area in September, followed by a major tropical depression which stalled directly in the study area in mid-October. In 1988, unseasonably calm, mild weather prevailed through late November, allowing remnants of *H. decipiens* meadows to persist there until the onset of the major winter cold fronts in early December. During the January 1989 sampling of that continental shelf, no traces of *H. decipiens*, and very little macroalgae, could be found. During that sampling cruise, the entire shelf appeared to be in a dormant condition, showing reduced fish and invertebrate activity as well as a lack of seagrasses.

Halophila engelmannii has been reported from depths of 295 ft (89.9 m) off the Dry Tortugas Bank (Zieman, 1982) and *H. decipiens* has been reported growing down to a depth of 138 ft (42.1 m) off St. Croix (Wiginton and McMillan, 1979). Both *H. decipiens* and *H. engelmannii* were seen growing to depths >82 ft (25 m) in the Florida Big Bend area (Continental Shelf Associates, Inc., 1988). In this study, *H. decipiens* was never seen growing below 122 ft (37.2 m).

Halophila decipiens growth is limited by light, salinity, and temperature (Trocine et al., 1982; Zieman, 1982; Dawes et al., 1989). It is a stenohaline species and shows a strong photoinhibitory response at light levels above 300 $\mu E/m^2/sec$. Its most efficient photosynthetic response is at lower irradiance levels (Dawes et al., 1989). Off the southwest coast of Florida, this species reaches its maximum density in depths between 70 and 90 ft (21.3 and 27.4 m); but substrate, rather than other environmental parameters, may contribute most to this observed abundance. Between the 70- and 90-ft (21.3- and 27.4-m) depth contours, there is a more or less continuous band or series of wave-sorted, fine sand ribbons which form ideal *H. decipiens* habitat. Closer to shore, there are large areas where thin sand covers a hard bottom; beyond 90 ft (27.4 m), there is an area where the sediments become coarser and show a greater concentration of algal rubble. Fine, well-packed sand appears again in the depth ranges beyond approximately 110 ft (33.5 m), but *H. decipiens* growth never again reaches densities seen in the 70- to 90-ft (21.3- to 27.4-m) depth range. *Halophila* decipiens was never found growing beyond a depth of 122 ft (37.2 m), although several areas of suitable substrate were surveyed.

4.3 TROPHIC IMPORTANCE OF DEEPWATER HALOPHILA DECIPIENS BEDS

Seagrass biomass in Thalassia and Syringodium beds is significantly correlated with invertebrate-species diversity and abundance, but this correlation is thought to result from the seagrass bed's structural complexity rather than its primary productivity. These beds represent a haven from predators rather than a food source for its residents (Heck and Wetstone, 1977; Coles et al., 1987). Within Halophila spp. seagrass beds, the associated faunal species and densities have been shown to be very similar to neighboring non-vegetated bottom (den Hartog, 1977). Very few marine organisms feed on seagrasses directly. The detrital food web is the primary pathway of trophic energy transfer from seagrass beds (Zieman, 1982).

Dirnberger and Kitting (1988), working on H. decipiens leaf damage off St. Croix, reported that only 2% of collected H. decipiens blades showed signs of herbivore grazing. They suggested that herbivores feed infrequently on H. decipiens because of sulphated phenolic acids reported in this species by McMillan et al. (1980).

The actual importance of H. decipiens production in the southwest Florida shelf ecosystem remains unclear. Data from this study indicate that a considerable tonnage of organic material is released into the system annually by this species. Further research needs to be done to determine the trophic significance of these deep seagrass beds.

5.0 CONCLUSIONS

5.1 HABITAT DIVERSITY

The habitat mosaic of hard bottom, and seagrass-algal communities upon the southwest Florida inner continental shelf from Sanibel Island southward to 25°N is extremely complex. Deep-growing seagrass and soft and hard coral communities may be present at any given location within this area. The low-relief, soft and hard coral flats seen here are separated by ribbons of wave-sorted, fine and coarse sediments where the seagrasses grow. During the growth season, *H. decipiens* appears almost ubiquitously across this shelf. Between June and late September, the entire inner-shelf area may be considered a live-bottom area under current MMS definitions.

South of 25°N, the portion of the study area directly off the mouth of Florida Bay is composed of a sandy silt, lime carbonate mud substrate, and no hard-bottom communities are seen until the Florida Keys. *Halophila decipiens* grows into the northern and southern edges of this silty mud area, but its presence there is limited.

Florida Bay shows a diverse pattern of benthic communities dominated by the three, perennial seagrass species. Listed in order of abundance, these species are:

1) *Thalassia testudinum*;

2) *Syringodium filiforme*; and

3) *Halodule wrightii*.

In terms of seagrass biomass, as well as a fish and invertebrate nursery area, Florida Bay appears to be the most productive habitat within this study area; however, the northern side of Florida's Lower Keys may turn out to be the equal of Florida Bay when it has been studied as thoroughly.

The northern side of the Lower Florida Keys shows considerable patch-reef development, along with extensive seagrass habitats dominated by *Thalassia*, *Syringodium*, and *Halodule*. Habitat distribution patterns in this area depend upon topographic features, substrate types, and the presence or absence of tidal channels linking the Gulf of Mexico and the Straits of Florida.

Patch-reef development is not as extensive in the Boca Grande Bank, Marquesas Keys, and Quicksands areas west of Key West, as on the northern side of the Lower Florida Keys, but a considerable amount of nearshore seagrass growth is still seen there.

Extensive and well-developed coral reefs surround the Dry Tortugas Bank at the Fort Jefferson National Monument. Habitats inside this atoll-like formation corresponded closely with the 1979 habitat map constructed for that area from 1976 aerial imagery.

5.2 SEASONALITY AND DEPTH LIMITS OF THE DEEP HALOPHILA DECIPIENS SEAGRASS BEDS

Halophila decipiens appears in significant amounts across this continental shelf from the early part of June through late October or early November, depending upon weather conditions. From its first appearance in early June, the biomass of these deep seagrass stands increases rapidly throughout June, July, and August. Biomass and relative proportions of larger to smaller blades within samples indicate a peak in the growing season in September. Decline sets in shortly after the growth season peaks, and these deep seagrass beds become progressively more susceptible to destruction by winter rough weather.

In September 1988, the mean biomass of H. decipiens from the southwest Florida inner shelf was 194.0 mg/m^2. Within the 70- to 90-ft (21.3- to 27.4-m) depth range, H. decipiens biomass was 287.0 mg/m^2. At all other depth ranges combined, mean H. decipiens biomass was 145.3 mg/m^2. The apparent biomass peak in the 70- to 90-ft (21.3- to 27.4-m) depth range was probably related to both the abundance of suitable substrate within those bathymetric contours and the improved photosynthetic response shown by H. decipiens at lower irradiance levels.

Below 100 ft (30.4 m), H. decipiens began to be replaced with a long, narrow-bladed growth form of C. prolifera. No H. decipiens was seen growing at depths >122 ft (37.2 m).

5.3 TROPHIC IMPORTANCE OF THE DEEP HALOPHILA DECIPIENS SEAGRASS BEDS

The estimated standing crop, based on mean biomass per m^2, in September of 1988, for H. decipiens across the inner southwest Florida continental shelf was 2,660 tons (2,359 metric tons). The actual role of this organic material in the southwest Florida shelf ecosystem remains unclear. By early January, all traces of H. decipiens leaves and rhizomes had disappeared from the surveyed shelf area. Some leaves had probably disintegrated and entered the detrital food chain, while others were swept off the inner shelf, providing a source of organic matter in deeper water.

6.0 REFERENCES CITED

Belderson, R. H., N. H. Kenyon, A. H. Stride, and A. R. Stubbs. 1972. Sonographs of the Sea Floor, Elsevier Publishing Company, New York. 185 pp.

Bohnsack, J. A. 1976. An investigation of a photographic method for sampling hard-bottom benthic communities. M.S. thesis, University of Miami. 188 pp.

Bohnsack, J. A. 1979. Photographic quantitative sampling of hard-bottom communities. Bull. Mar. Sci. 29(2):242-252.

Coles, R. G., W. J. Lee Long, B. A. Squire, and J. M. Bibby. 1987. Distribution of seagrasses and associated juvenile commercial penaeid prawns in North-eastern Queensland waters. Aus. J. Mar. Freshw. Res. 38:103-119.

Continental Shelf Associates, Inc. 1985. Southwest Florida Shelf Regional Biological Communities Survey Marine Habitat Atlas. Prepared for the U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, Metairie, LA. (Habitat Maps).

Continental Shelf Associates, Inc. 1987a. Southwest Florida Shelf Regional Biological Communities Survey. A final report submitted to the U.S. Department of the Interior, Minerals Management Service, New Orleans, LA. Contract No. 14-12-0001-29036. 3 vol.

Continental Shelf Associates, Inc. 1987b. Assessment of Hurricane Damage in the Florida Big Bend Seagrass Beds. A final report for the U.S. Department of the Interior, Minerals Management Service, New Orleans, LA. Contract No. 14-12-0001-30188.

Continental Shelf Associates, Inc. 1988. Monitoring of Drillsite A in the Gainesville Area OCS Block 707. A final report presented to Sohio Petroleum Company, Lafayette, LA. 131 pp.

Continental Shelf Associates, Inc. and Martel Laboratories, Inc. 1985. Florida Big Bend Seagrass Habitat Study Narrative Report. A final report for the Minerals Management Service, Metairie, LA. Contract No. 14-12-0001-30188.

Danek, L. J. and G. S. Lewbel (ed.). 1986. Southwest Florida Shelf Benthic Communities Study--Year 5 Annual Report. A final report by Environmental Science and Engineering, Inc. and LGL Ecological Research Associates, Inc. submitted to the U.S. Department of the Interior, Minerals Management Service, New Orleans, LA. Contract No. 14-12-0001-30211.

Davis, G. E. 1979. Outer Continental Shelf Resource Management Map, Coral Distribution, Fort Jefferson National Monument, The Dry Tortugas. New Orleans OCS Office, Bureau of Land Management (1 Map).

Dawes, C. J., C. S. Lobban, and D. A. Tomasko. 1989. A comparison of the physiological ecology of the seagrasses Halophila decipiens Ostenfeld and H. johnsonii Eiseman from Florida. Aquat. Bot. 33:149-154.

den Hartog, C. 1977. Structure, function, and classification in seagrass communities, pp. 89-121. In: McRoy, C. P. and Helfferich, C. (eds.) Seagrass Ecosystems: A Scientific Perspective.

Dirnberger, J. M. and C. L. Kitting. 1988. Browsing injuries to blades of Halophila decipiens within a deep seagrass meadow. Aquat. Bot. 29:373-379.

Dustan, P. and J. C. Halas. 1987. Changes in the reef-coral community of Cargsfort Reef, Key Largo, Florida: 1974 to 1982. Coral Reefs 6:91-106.

Environmental Science and Engineering, Inc., LGL Ecological Research Associates, Inc., and Continental Shelf Associates, Inc. 1987. Southwest Florida Shelf Ecosystems Study Data Synthesis Report. A final report prepared for the U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. Contract No. 14-12-0001-30276.

Heck, K. L., Jr. and G. S. Wetstone. 1977. Habitat complexity and invertebrate species richness and abundance in tropical seagrass meadows. J. Biog. 4:1135-1142.

Hoffmeister, J. E. and H. G. Multer. 1968. Geology and origin of the Florida Keys. Geol. Soc. Am. Bull. 79:1487-1502.

Hudson, J. H. 1985. Growth rate and carbonate production in Halimeda opuntia, Marquesas Keys, Florida, pp. 257-263. In: Toomey, D. F. and Nitecki, M. H. (eds.) Paleoalgology: Contemporary Research and Applications, Springer-Verlag, Berlin.

Iverson, R. L. and H. F. Bittaker. 1986. Seagrass distribution and abundance in eastern Gulf of Mexico coastal waters. Est. Coast. Shelf Sci. 22(5):577-602.

Jaap, W. C., W. G. Lyons, P. Dustin, and J. C. Halas. 1989. Stony coral (Scleractinia and Milleporina) community structure at Bird Key Reef, Fort Jefferson National Monument, Dry Tortugas, Florida. Florida Marine Research Publications Number 46. Florida Marine Research Institute, St. Petersburg, FL. 31 pp.

McMillan, C., O. Zapata, and L. Escobar. 1980. Sulphated phenolic compounds in seagrasses. Aquat. Bot. 8:267-278.

National Park Service. 1985. Florida Bay Habitat Map. Everglades National Park, Homestead, FL.

Schmidt, T. W. 1979. Ecological study of fishes and water quality characteristics of Florida Bay, Everglades National Park, Florida. National Park Service, South Florida Research Center, Homestead, FL. Rep. No. RSP-EVER N-36. 145 pp.

Shinn, E. A., D. W. Holmes, J. H. Hudson, D. M. Robbin, and B. H. Lidz. 1982. Non-oolitic, high-energy carbonate sand accumulation, the Quicksands, southwest Florida Keys (abst.). Am. Assoc. Petrol. Geol. Bull. 66:629-630.

Shinn, E. A., B. H. Lidz, J. L. Kindinger, R. B. Halley, and J. H. Hudson. 1989. A Field Guide: Reefs of Florida and the Dry Tortugas. Prepared for the 28th International Geological Congress, Washington, D.C. U.S.A., July 9-19, 1989. 47 pp.

Thompson, M. J. and N. W. Phillips. 1987. Resource inventory of the Florida Big Bend region. In: Proceedings of the Tenth National Conference of the Coastal Society. 12-15 October 1986, New Orleans, LA.

Thompson, M. J., A. D. Hart, and C. W. Kerlin. 1989. Exposure of deep seagrass beds off the west coast of Florida to discharged drilling effluents. In: Engelhardt, F. R., Ray, J. P., and Gillam, A. H., ed., Drilling Wastes. Proceedings of the 1988 International Conference on Drilling Waste. Calgary, Alberta, Canada, 5-8 April 1988. Elsevier Applied Science Publishers Ltd., London.

Trocine, B. P., J. D. Rice, and G. N. Wells. 1982. Photosynthetic response of seagrasses to UV-A radiation and the influence of visible light intensity. Plant Physiol. 69:341-344.

Virnstein, R. and K. Cairns. 1986. Seagrass maps of the Indian River Lagoon. Seagrass Ecosystems Analysis, Vero Beach, Florida.

Wiginton, J. R. and C. McMillan. 1979. Chlorophyll composition under controlled light conditions as related to the distribution of seagrasses in Texas and the U.S. Virgin Islands. Aquat. Bot. 6:171-184.

Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1983. Southwest Florida Shelf Ecosystems Study - Year 1. A report for the U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Office, Metairie, LA. Contract No. 14-12-0001-29144.

Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1985. Southwest Florida Shelf Ecosystems Study - Year 2. A report for the U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, Metairie, LA. Contract No. 14-12-0001-29144. 7 vol.

Zieman, J. C. 1982. The ecology of seagrasses of south Florida: A community profile. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-82/25. 158 pp.

Zieman, J. C., J. W. Fourqurean, and R. L. Iverson. 1989. The distribution and productivity of seagrass and macroalgae in Florida Bay. Bull. Mar. Sci. 44(1):292-311.

APPENDICES

APPENDIX A

PHOTOGRAPHIC ESTIMATION OF *HALOPHILA DECIPIENS* BIOMASS

The photographic techniques used to estimate seagrass blade density and leaf biomass for surveyed species of Halophila decipiens has been developed over a number of Continental Shelf Associates, Inc. studies. Halophila spp. lend themselves to a photographic approach to estimating blade density because of their growth form. They grow low to the ground, produce flat leaves, and have very little below ground biomass. Because the blades are so low to the substrate a camera mounted on a fixed framing device has sufficient depth of field to bring an entire sample quadrant into focus.

Following early experiments with the photographic estimation of blade density and biomass, a photographic sampling quadrat covering 0.1 m^2 was selected as a standard photo sample size. Generally 10 photo quadrats are sampled at a station. In early studies Halophila blades were collected at each station, but not from the identical photo quadrats sampled. These collections were returned to the laboratory, measured, then dried and weighed to determine a length/weight relationship between the individual leaves. Because Halophila blades are so small, size categories of blade lengths had to be established and blades grouped together in order to obtain measurable weights. Blade size ranges selected were 0 to 5, 6 to 10, 11 to 15, 16 to 20, 21 to 25, and 26 to 30 mm. Table A-1 list the total number of leaves measured, total weight of these leaves, and the mean dry weight biomass per blade established for each of these categories.

Photo transparencies of the sample quadrats were returned to the laboratory, projected onto a screen, and all visible Halophila blades were counted. Following the blade count of an individual photo frame, all blades showing the proper orientation were measured. "Blades showing proper orientation" were defined as those blades lying flat with respect to the camera lens allowing an accurate length measurement to be made. Generally only 60 to 80% of the blades counted had the proper orientation to allow accurate measurement. It was assumed that the percentage a given blade size range made up in the measured sample represented the percent composition of that blade size range in the total photo quadrat sample count. For example, if 80 blades were counted in a sample frame and only 70 blades could be measured, and if blades ranging from 6 to 10 mm in length made up 30% of the 70 blades measured (21 blades), then it was assumed that blades in the 6 to 10 mm size range made up 30% of the total 80 blades present (24 blades).

The numbers of blades in each size range in each of the sampled photo quadrats were summed. Using the mean dry weight biomass for leaves in each blade length range, biomass was estimated for each seagrass sample station.

In subsequent surveys 13 quadrats were sampled photographically then meticulously harvested in order to check the photographically estimated biomass against actually measured biomass. Four questions were addressed consecutively in order to assess the effectiveness of the photographic technique. These questions were:

1) What is the relationship between leaf length classes and leaf biomass?;

Table A.1. Leaves measured in each size range category then dried to establish mean biomass per blade for each category.

Size Category (mm)	Total Blades Measured and Dried	Total Dry Wt (mg)	Mean Biomass per blade (mg)
0-5	433	7.3	0.0169
6-10	2427	200.4	0.0826
11-15	1512	313.3	0.2072
16-20	782	432.8	0.5419
21-25	90	69.0	0.7666

2) What is the relationship between the photographic leaf count and the number of harvested leaves?;

3) What is the relationship between the estimated leaf size composition of a sample and the collected leaf size composition of that sample?; and

4) What is the relationship between the photographically estimated dry weight biomass and the measured dry weight biomass?

Figure A-1 shows the linear and logarithmic regression lines between the six size range categories and the mean biomass of leaves in each individual category. As the Halophila blades elongate, their biomass initially goes up rapidly then begins to level off. The r^2, coefficient of determination for the logarithmic curve shown in Figure A-1 is 0.95 while the linear regression coefficient of determination (r^2) is only 0.90.

Table A-2 shows the photographically estimated and measured blade counts and dry weight biomass from each of the 13 test quadrats. Figure A-2 shows the linear regression line between photo-estimated (y axis) and measured (x axis) blade counts. The correlation coefficient (r) for this linear regression is 0.96 and coefficient of determination (r^2) is 0.92.

Table A-3 compares the photo estimated leaf counts per size range category with actual counts of the leaves in each size range category. Table A-4 shows the linear regression correlation coefficients (r) and coefficients of determination (r^2) for the estimated leaves per size range category against the actually collected leaves per size range category. Correlations, while low in the 16 to 20 and 21 to 25 mm class, are statistically significant in all size range categories. Two factors are thought to account for the variation between estimated and counted blades in each size classification range. These factors were:

1) Many blades measuring at the upper ends of their assigned size range in the photo transparency actually crossed the arbitrary dividing point into the next class when spread out on a flat surface and measured; and

2) The larger leaves, because of their size, are more likely to be twisted or bent into angles where they can not be measured in the photo analysis.

Figure A-3 shows the linear regression line between photo-estimated and measured dry weight biomass. The correlation coefficient (r) of this regression line is 0.91 and the coefficient of determination (r^2) is 0.82. The relationship between photo-interpreted biomass and measured biomass for the 13 test quadrats is defined by the equation:

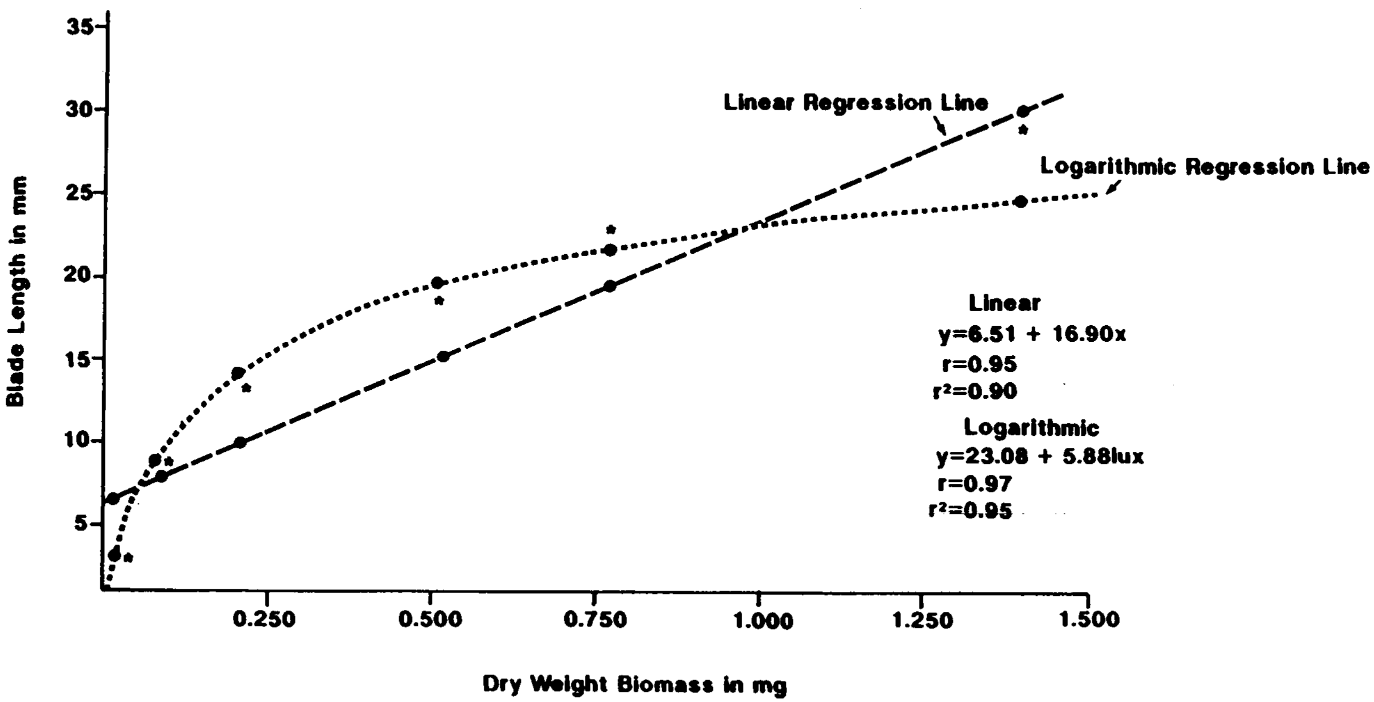

Figure A-1. Linear and logarithmic regression lines for blade length categories against dry weight biomass.

Table A.2. Photographically estimated and measured blade counts and biomass from 13 test quadrats.

Quadrat	Photo Blade Count	Sampled Blade Count	Photo Estimate Biomass (mg)	Measured Biomass (mg)
1	70	103	21.9	78.2
2	31	60	11.8	32.7
3	67	92	21.1	62.0
4	25	26	7.9	16.1
5	86	89	28.4	47.4
6	109	133	30.4	75.4
7	55	97	15.5	46.6
8	36	54	7.4	33.3
9	167	207	47.7	152.2
10	130	163	25.5	90.9
11	138	215	34.6	123.8
12	54	77	8.2	44.7
13	84	101	22.2	71.4

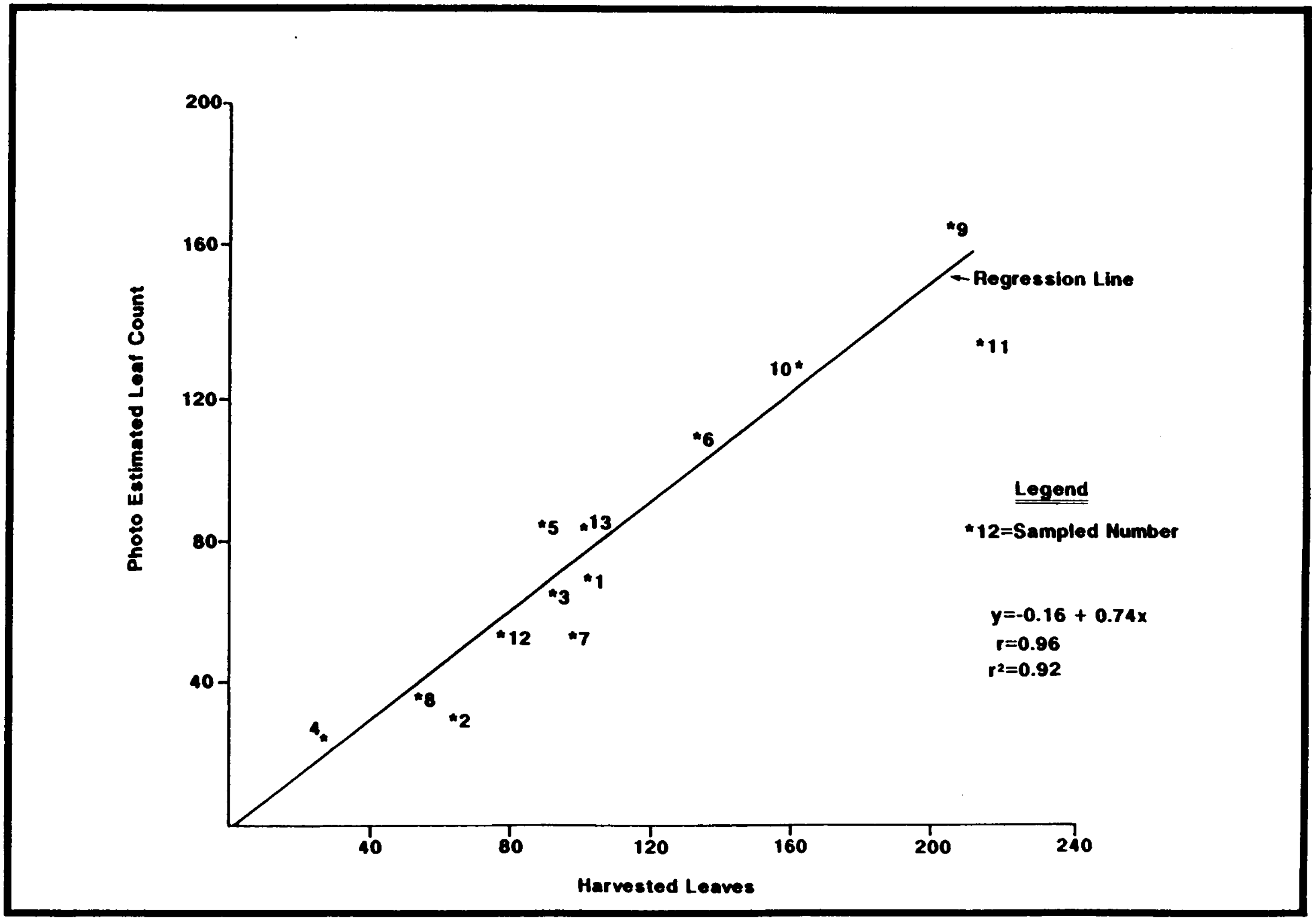

Figure A-2. Linear regression line for photographic leaf counts against harvested leaves.

Table A.3. Photo estimated and counted blades per size class.

	Photo Estimates					Sample Counts				
Sample	0-5	6-10	11-15	16-20	21-25	0-5	6-10	11-15	16-20	21-25
1	4	17	30	16	3	15	27	33	26	2
2	0	13	4	7	7	2	8	28	16	5
3	0	17	35	13	2	3	6	41	39	3
4	0	9	9	7	0	1	3	7	15	0
5	3	13	54	16	0	4	14	35	36	0
6	4	36	57	12	0	6	7	55	61	4
7	6	17	19	13	0	11	27	36	23	0
8	8	12	17	0	0	5	29	19	1	0
9	8	55	76	28	0	13	58	102	29	4
10	9	77	42	2	0	18	88	53	4	0
11	11	51	65	11	0	24	60	110	20	1
12	8	33	13	0	0	15	46	16	0	0
13	8	29	34	13	0	10	30	46	15	0
Total	69	379	455	138	12	127	403	581	285	19

Table A.4. Correlation coefficients of estimated and harvested blades by size class.

Size Category (mm)	Correlation Coefficient (r)	Coefficient of Determination (r^2)
0-5	0.84	0.71
6-10	0.87	0.77
11-15	0.86	0.74
16-20	0.61	0.37
21-25	0.63	0.34

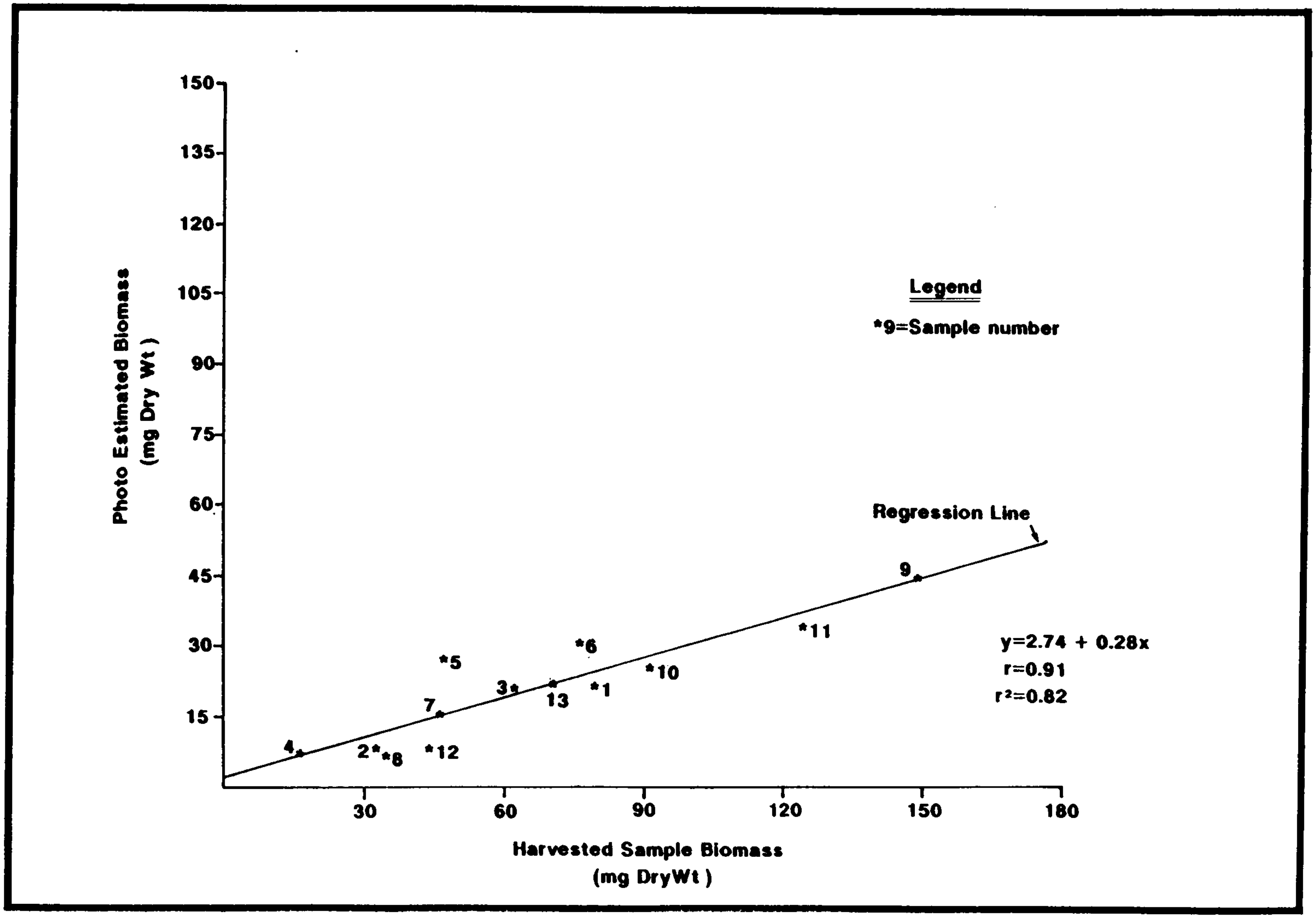

Figure A-3. Linear regression line for photo estimated biomass against measured biomass.

Photographically Estimated Biomass = 2.47 + 0.28 Measured Biomass

These tests show a clear, consistent and statistically valid relationship between photographically estimated biomass and harvested biomass for the tested *H. decipiens* quadrants. In order to develop accurate estimates of *H. decipiens* biomass across large areas, a certain subset of the photographically sampled quadrants must be collected, dried, and weighed from each sampling period and a predictive equation developed as illustrated above. Photographically estimated biomass alone will be chronically lower than harvested biomass due to under counting of blades in the photo quadrants.

APPENDIX B

POST-1987 SEAGRASS DIE OFF IN FLORIDA BAY

During 1987, a major seagrass die off began in Florida Bay. Large areas of dead seagrass associated with a line of dead and dying fish off Cross Bank in the Central Bay Area were first reported in July 1987 by Dr. George Powell (National Audubon Society, personal communication in Robblee, 1988) and Jim Fourqurean (University of Virginia, personal communication in Robblee, 1988). In August of 1987, an accumulation of dead seagrass was reported by Dr. Mike Robblee (National Park Service) to the east of Buoy Key in Rankin Lake. In January and February of 1988, Dr. Robblee observed patches of seagrass die off in Johnson Key Basin. By May 1988, the Florida Keys Guide Fishing Association was reporting large areas within Central Florida Bay where seagrasses were apparently dying (Robblee, 1988). By January of 1989, die off was reported from Sunset Cove adjacent to Key Largo. By March of 1989, reports of die off were coming in from Pine Channel in the Lower Keys, and the Whitewater Bay and Ponce de Leon Bay areas of the Everglades National Park (Robblee, 1989a). Figure B-1 is a qualitative estimate by Dr. Mike Robblee of the seagrass areas affected by die off in Florida Bay as of March 1989.

Aerial and SPOT satellite data were used to track and quantify the progress of seagrass die off in the hardest hit areas of the Central Florida Bay basins shown in Figure B-2 (Thompson and Robblee, 1989). No seagrass die off was indicated in the SPOT panchromatic data from February 1987. In the October 1987 aerial imagery flown for the Southwest Florida Nearshore Benthic Habitat Study, only one small area of seagrass die off near Buoy Key in Rankin Lake could be definitely identified. Multispectral SPOT data from December 1987 also failed to distinctively show any areas of major seagrass die off, although one small area within Rabbit Key Basin may indicate early onset of the die off later seen there. By June of 1988, SPOT satellite panchromatic data indicated 2,008 ac (813 ha) of seagrass had been wiped out and another 3,781 ac (1,530 ha) of seagrass was severely impacted. By November of that year, these figures had risen to a total of 4,077 ac (1,650 ha) wiped out and 5,908 ac (2,391 ha) impacted (Table B.1).

Between February 1987 and November 1988, 32% of the seagrass community within Rankin Lake, Johnson Key Basin, and Rabbit Key Basin was impacted by seagrass die off, with 22% of this community being wiped out (Table B.1). Rankin Lake, the basin closest to the mainland and where the seagrass die off was first noticed by National Park Service personnel, was the area hardest hit; Rabbit Key Basin in the center of Florida Bay showed the second highest seagrass acreage loss; and Johnson Key Basin, to the west of Rabbit Key Basin, was the least affected.

Dr. Joseph Zieman (1988) provided the following description in a report to the National Park Service, paraphrased here, of the progressive stages in seagrass bed deterioration. Seagrass die off occurs primarily in areas of very high seagrass density and the die off phenomenon affects *Thalassia testudinum* almost exclusively, especially in its preliminary stages. In its early stages, where dead and damaged seagrasses comprise <10% of a seagrass bed, the beds take on a speckled or dotted appearance when viewed from the air. These dots or speckles represent small, circular or crescent-shaped patches in which the *Thalassia* blades have lost turgor and are lying on the bottom although

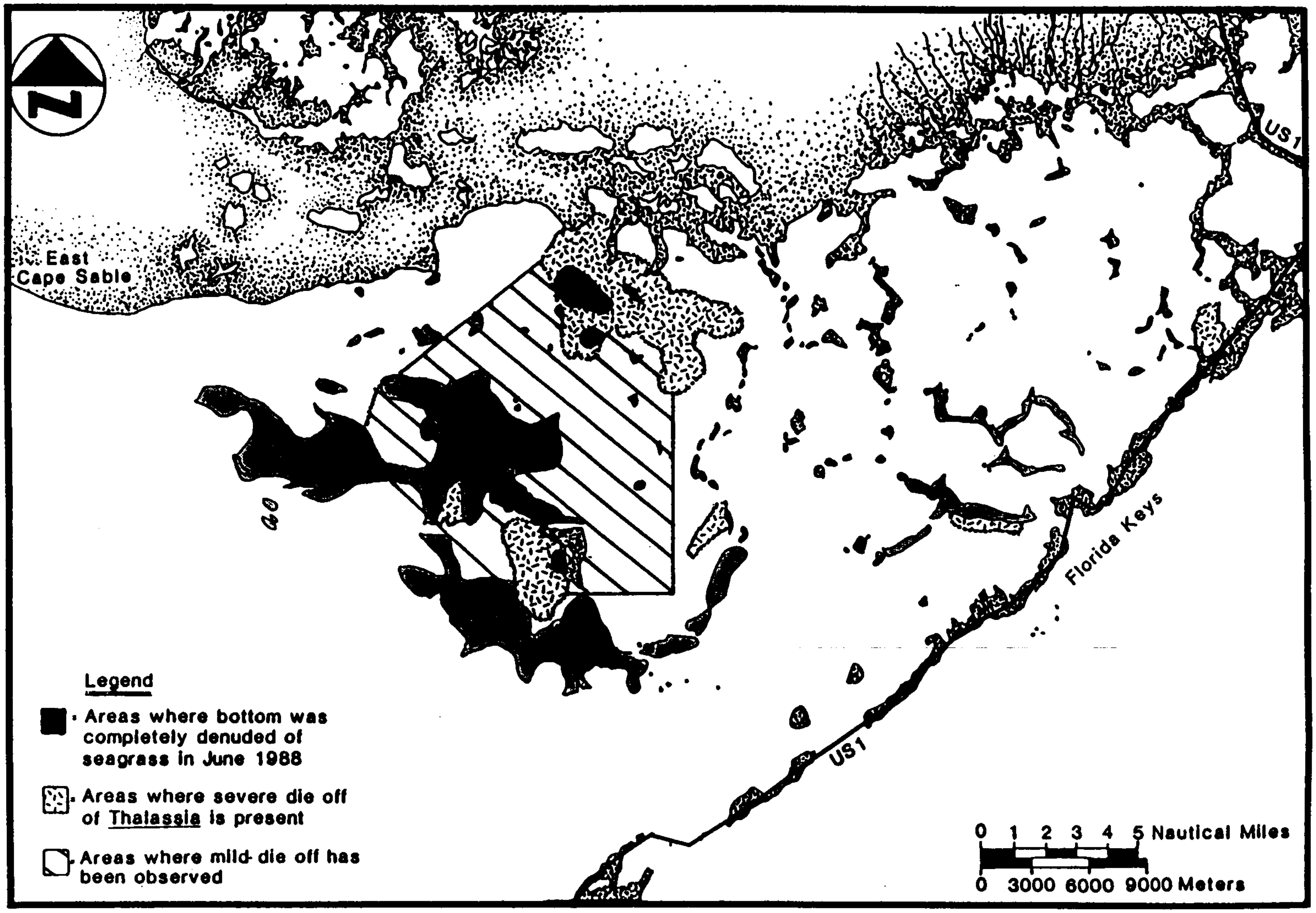

Figure B.1. Florida Bay seagrass die off in March of 1989.

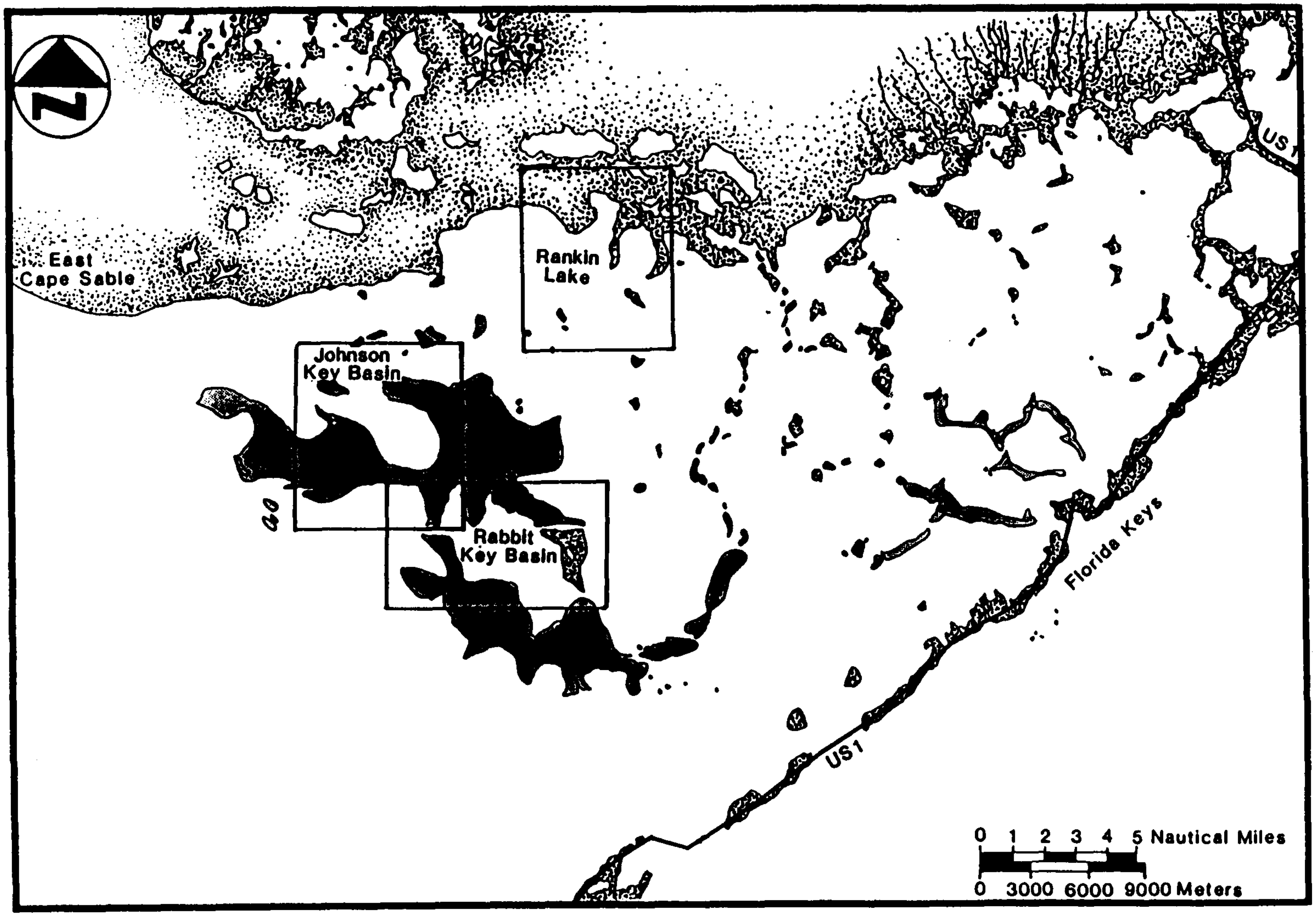

Figure B.2. Central Florida Bay basins most affected by seagrass die off.

Table B.1. Seagrass die off in the basins of central Florida Bay based on analysis of SPOT satellite panchromatic data.

Affected Basin	February 1987 Acres	June 1988 Acres	November 1988 Acres
Rankin Lake			
Total Seagrass Acreage	6,281	--	--
Impacted Acreage	--	2,878	3,840
Denunded Acreage	--	1,960	3,795
Johnson Key Basin			
Total Seagrass Acreage	4,486	--	--
Impacted Acreage	--	565	472
Denunded Acreage	--	3	70
Rabbit Key Basin			
Total Seagrass Acreage	7,528	--	--
Impacted Acreage	--	338	1,596
Denunded Acreage	--	45	212

still attached to their short shoots. Die off proceeds outward from the edges of these speckles; in the intermediate stage of the phenomenon, dead areas within the affected seagrass beds comprise 20 to 50% of the beds' surface area. The speckled patterns observed earlier have now grown and merged together to form large bare areas within what otherwise appears to be a healthy T. testudinum seagrass bed. Severely damaged seagrass beds, show dead areas covering 50 to 90% of their surface area. In these heavily damaged seagrass beds the small remaining stands of healthy Thalassia take on the appearance of "islands" within bare bottom areas. At this stage, water clarity has begun to deteriorate due to the loss of sediment stability previously provided by the seagrass bed. In the final, or totally destroyed stage, there is no living seagrass and very little macro- or drift-algae seen within the area.

Several hypotheses have been proposed to account for the observed deterioration of seagrass beds seen in Florida Bay. Dr. Robblee (1988) has grouped these various theories into three major categories. These are:

I) The seagrass die off was caused by factors affecting the respiration and production within the benthic plant community.

Several possible mechanisms are proposed to support this hypothesis:

1) Environmental stress, possibly high temperature and/or high salinity, resulted in an increased respiratory demand that the benthic plant community was unable to meet;

2) Reduced production within the dense seagrass beds allowed sediment sulfide levels to become toxic (Yarbro et al., 1989);

3) High temperature and low-water levels in Florida Bay caused seagrass exfoliation across the banks; this extensive leaf litter accumulated in the basins, shading out the seagrass beds there; and/or

4) Two or more of the above conditions may have acted synergistically to trigger the initial seagrass die off, instigating a snow-ball effect.

Evidence supporting the above hypothesis consist of the facts:

1) Severe die off has occurred most noticeably in the relatively deeper portions of the affected basins where the seagrass community, both above ground and below ground, is very well-developed. Although seagrasses on the banks exfoliate or shed their leaves in times of environmental stress, no areas of seagrass die off have been detected upon the banks themselves;

2) The most affected areas (i.e., Rankin Lake, Johnson Key Basin, and Rabbit Key Basin) are all characterized by restricted flushing and more extreme environmental conditions;

3) High oxygen demands are associated with the large amounts of plant material known to be accumulating in the basins of central Florida Bay. In such a situation, the seagrass community may normally exist in a precarious balance between respiration and production. Relatively little environmental stress would be required to push such a community "over the edge."

The summer of 1987 was the hottest summer on record world-wide. A condition of calm and low water also prevailed across Florida Bay during that time period (Robblee, 1988).

II) The seagrass die off was caused by a pathogen.

Evidence supporting this suggestion consist of:

1) The die off began as small patches which spread and coalesced into larger areas as if an infection were spreading;

2) The fact that seagrass die off in Florida Bay continues from year to year, and spreads from place to place, suggests a disease mechanism for the observed die off rather than environmental stress;

3) An undescribed species of the slime mold *Labyrinthula*, which caused the world-wide die off of *Zostera marina* beds in the 1930s, has been isolated in the dying seagrass areas of Florida Bay (Porter and Muehlstein, 1989); and

4) Novel branching patterns observed in *Thalassia* short shoots taken from die-back and dying fringe areas may suggest a response to some type of pathogen (Durako, 1989).

III) The seagrass die off resulted from the eutrophication of western Florida Bay.

At the present time, there is little evidence to support this hypothesis, at least for the die offs observed in central Florida Bay. Florida Bay is essentially a nutrient-poor or oligotrophic system. No increase in nutrient levels or decrease in water clarity was observed prior to the beginning of the seagrass die off. Once die off was in progress, nutrient levels in the water column

> rose due to the release of nutrients bound up in the above-ground and below-ground biomass of the decimated beds. Increases in the water-column nutrients due to seagrass death may well be one of the synergistic factors favoring continuation and spread of seagrass die off; however, most researchers do not feel it is a primary cause in itself.

Zieman et al. (1989) have proposed a conceptual model for the Florida Bay seagrass die off. They maintain that distal causes included: 1) the curtailment of freshwater flow through the Everglades, which has allowed extensive Thalassia beds to develop in areas of Florida Bay once too fresh for them; and 2) the abnormal length of time that has elapsed since the last hurricane disturbed communities within Florida Bay. Both these factors had allowed Thalassia communities to become extremely dense and to develop tremendous amounts of below-ground biomass which had to be supported by the above-ground, respiring portion of the plant. As biomass production continued, the Thalassia communities within the basins of Florida Bay were pushed closer and closer to their respiratory limits. The potential triggers for the actual die off under this model include:

1) The abnormally high temperatures of the 1987 summer;

2) Extreme salinities; and

3) Disease.

Zieman et al. (1989) proposed the scenario that due to the extreme temperatures, the leaves of seagrasses on the banks exfoliated and accumulated within the basins. The addition of this decaying plant matter to the already oxygen-stressed basins pushed the plants there beyond their respiratory limits, and die off began as a result of hypoxia. Once the seagrasses around the margins of the basins began dying, a synergistic, or positive growth loop, was formed in which dead and decaying plants released nutrients into the water column, increasing the biological oxygen demand, and farther inhibiting photosynthesis and respiration by turbidity due to algal blooms and reduced sediment stability. In this stressed, nutrient-rich environment, it is easy to conceive of a disease pathogen, normally inactive or relatively benign, becoming lethal. If the Zieman et al. (1989) model is correct, seagrass die off will continue until this positive feed back loop reaches equilibrium within Florida Bay.

Observations since 1987 indicate that although the causative mechanisms of the seagrass die off are associated with the extreme environmental conditions of summer, the effects of seagrass die off in terms of observable expansion in dead-bottom areas, are not fully seen until the following winter. There is some evidence that Halodule wrightii is beginning to recolonize denuded-bottom areas (Robblee, 1989b); and in some areas, the macroalga Batophora spp. is beginning to cover bottom previously stripped of seagrasses (Paul Carlson, 1989, personal communication, Florida Department of Natural Resources). No remote-sensing data is available for 1989; consequently the spread of die-off area since November 1988 has not been quantified.

Regardless of its causes, the seagrass die off in Florida Bay has dramatically altered community structure there. By November 1988, the 5,908 ac (2,391 ha) of seagrass impacted represented a loss of 47,447 tons (43,043 metric tons) of above- and below-ground biomass to the system. Even if the die off is restricted to the densest Thalassia beds within the Bay, well over 100,000 ac (40,470 ha) may eventually be affected. The ecological ramifications of this type of loss is enormous; considering that Florida Bay is the major nursery ground for the fish and invertebrate species seen across the entire southwest Florida shelf, such a loss spreads far beyond the boundaries of Florida Bay. This continuing situation needs to be monitored closely by all regulatory agencies having interest in the eastern Gulf of Mexico or the Straits of Florida.

REFERENCES CITED

Durako, M. J. 1989. Anatomical characteristics and recovery potential of Thalassia testudinum in sites affected by die-back in Florida Bay, p. 22. Tenth Biennial International Estuarine Research Conference, October 8-12, 1989, Baltimore, MD (Abstract only).

Porter, D. and L. K. Muehlstein. 1989. The role of fungi and slime molds in the die-back of Thalasia testudinum in Florida Bay, p. 65. Tenth Biennial International Estuarine Research Conference, October 8-12, 1989, Baltimore, MD (Abstract only).

Robblee, M. B. 1988. Update of seagrass die-off in Florida Bay. September 16, 1988 internal memorandum, National Park Service, Everglades National Park, Homestead, FL.

Robblee, M. B. 1989a. Update of seagrass die-off in Florida Bay. March 22, 1989 internal memorandum, National Park Service, Everglades National Park, Homestead, FL.

Robblee, M. B. 1989b. Changes in benthic fauna associated with an extensive seagrass die-off in western Florida Bay, p. 69. Tenth Biennial International Estuarine Research Conference, October 8-12, 1989, Baltimore, MD (Abstract only).

Thompson, M. J. and M. B. Robblee. 1989. Remote monitoring of seagrass die off in Florida Bay, Everglades National Park, Florida, p. 82. Tenth Biennial International Esutarine Research Conference, October 8-12, 1989, Baltimore, MD (Abstract only).

Yarbro, L. A., P. R. Carlson, Jr., S. Benford, and T. A. Tedesco. 1989. Sediment sulfide and physiological characteristics of Thalassia testudinum in die-back areas of Florida Bay, p. 92. Tenth Biennial International Estuarine Research Conference, October 8-12, 1989, Baltimore, MD (Abstract only).

Zieman, J. C. 1988. Zieman Description. In: Robblee, M. B., 1988 Update of seagrass die-off in Florida Bay. September 16, 1988 internal memorandum, National Park Service, Everglades National Park, Homestead, FL.

Zieman, J. C., J. W. Fourqurean, and R. T. Zieman. 1989. The Florida Bay seagrass die-off: Process changes, potential causes, and a conceptual model, p. 92. Tenth Biennial International Estuarine Research Conference, October 8-12, 1989, Baltimore, MD (Abstract only).

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.