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MMS 87-0107

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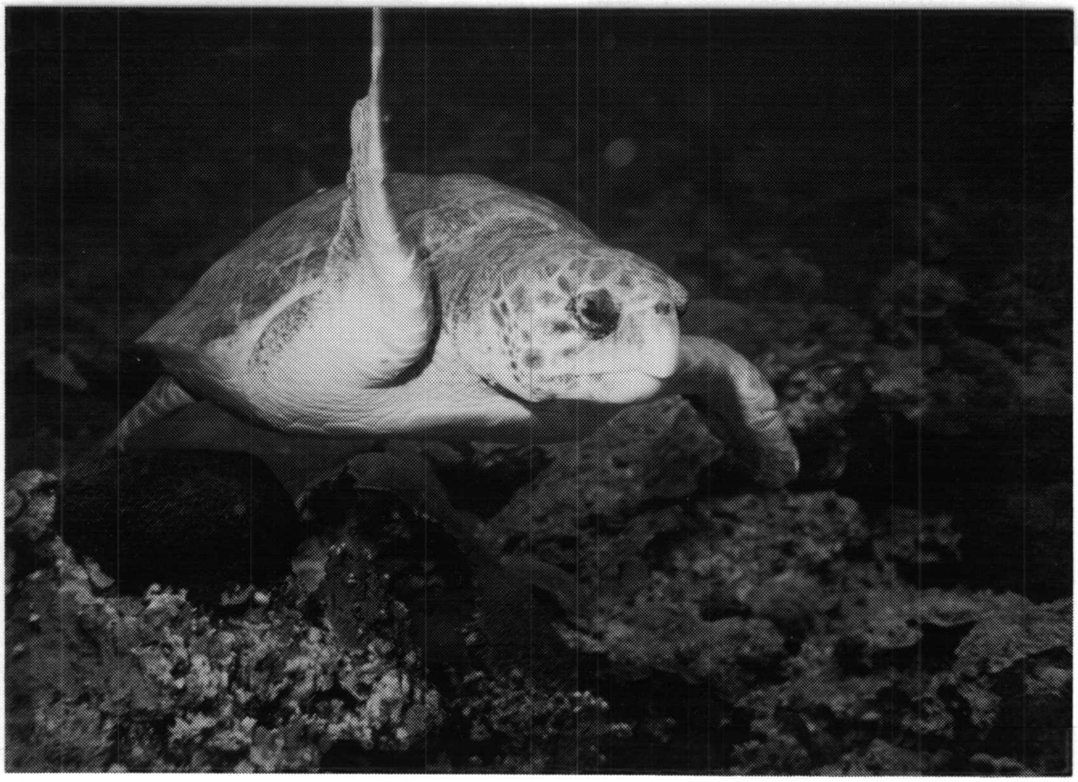

MMS
U.S. Department of the Interior
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Underwater Sightings of Sea Turtles in the Northern Gulf of Mexico

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Prepared under MMS Purchase Order No. 14549

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

October 1987

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CITATION

This study should be cited as:

Rosman, I, G.S. Boland, L.R. Martin and C.R. Chandler. 1987. Underwater sightings of sea turtles in the northern Gulf of Mexico. U.S. Dept. of the Interior. Minerals Management Service. OCS Study/MMS 87/0107. 37 pp.

Abstract

Data from eight scientific studies in the northern Gulf of Mexico conducted between 1975 and 1985 were reviewed for information concerning underwater sightings of sea turtles. Records of 1024 scuba dives, 909 h of underwater video and submersible observations, and some 1500 days of time-lapse photographic observation were compiled from published reports, data logs, and photographic material. This yielded 268 verifiable underwater sightings of sea turtles, 231 of which came from time-lapse cameras emplaced on live-bottom areas off southwest Florida. The majority of turtle sightings that could be identified to species were of loggerheads, although three leatherbacks and one Kemp's ridley were seen. Diver sightings documented residency of individual loggerheads at specific sites for periods of up to nine months and provided descriptions concerning the manner in which turtles utilized underwater structures. Time-lapse results indicated a distinct diel pattern in the frequency of sightings; from a total of 211 sightings, means of 4.2 sightings per daylight hour and 14.1 sightings per nighttime hour were obtained. A significant increase in the daily occupation rate by turtles was observed at a camera array that remained in place for two years. Utilization of underwater structures appears to consist of brief (1 to 5 h) intervals of relative inactivity, but not total dormancy. The mean residency time per day estimated from the time-lapse data was 1.85 ± 2.018 h S.E.

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Introduction

Descriptions of the distribution of sea turtles in the northern Gulf have been based on aerial surveys (Fritts et al., 1983) and compilation of anecdotal sightings by fishermen and others, including divers (Fuller and Tappan, 1986). Behavioral studies have concentrated on the sea turtles' activity at or near nesting beaches where they are easily observed (Carr, 1982). Underwater behavior has been noted regarding their remarkable ability to hibernate submerged for periods of a month or longer (Felger et al., 1976; Carr et al., 1980). However, scientific accounts of distribution and active behavior based on underwater sightings are limited. We have reviewed extensive records of underwater observations made during eight separate scientific studies in the northern Gulf of Mexico conducted between 1975 and 1985. We compared the occurrence of turtles in western, central, and eastern portions of this region and their occurrence over different types of natural and artificial substrate. Evidence of diel activity patterns was noted and the efficacy of different techniques for underwater observation of turtles was compared. Evidence for the recruitment of turtles to underwater structures was considered.

Four species of sea turtles commonly occur in the northern Gulf of Mexico: in the family Cheloniidae, the green (Chelonia mydas), the loggerhead (Caretta caretta), the Kemp's ridley (Lepidochelys kempi), and in the family Dermochelyidae, the leatherback (Dermochelys coriacea) (Leary, 1957; Rebel, 1974; Carr, 1982; Fritts et al., 1983). Two other species, the hawksbill (Eretmochelys imbricata) and the olive ridley (Lepidochelys olivacea), have been reported in the southern Gulf of Mexico and may occasionally range north into U.S. waters (Rebel, 1974; Witzell, 1983). Populations of sea turtles in the northern Gulf of Mexico have decreased markedly from their historical levels due to a variety of human activities that affect adults, juveniles, hatchlings, and eggs

(King, 1982; Ross, 1982). Adults were taken at sea for meat, shell, and hide; and eggs were gathered from nesting beaches for food. Accidental mortality has been caused by collisions with boat propellers, entrainment in harbor dredges, incidental capture in fishing gear, contact with pollutants, and development of critical nesting beaches (Mager, 1985). Recently the offshore energy-industry has been implicated in sea-turtle injuries or mortalities caused by underwater demolitions used to remove retired production platforms (Klima, 1986).

Under the Endangered Species Act of 1973, the Kemp's ridley, leatherback and hawsksbill sea turtles are listed as endangered, while the other two species that occur in the northern Gulf of Mexico,the green and loggerhead sea turtles are assigned threatened status. The Act outlaws the taking of these species for human consumption and proscribes activities that may cause accidental mortality (Mager, 1985). With a ban on turtle fishing in force, and with vigorous efforts underway to protect nesting beaches and re-establish breeding populations (Klima, 1986), concern for protection of sea turtles has focused on prevention of accidental mortality. Information on the distribution and behavior of sea turtles in areas where such mortality is likely to occur is therefore needed.

Methods and Materials

Data from eight scientific research studies were reviewed for the purpose of compiling underwater observations made in areas where sea turtles are known to occur (Table 1). These studies were designed as surveys of marine megafauna, including sea turtles, in nearshore and offshore habitats of the northern Gulf of Mexico (Figure 1). Sightings of sea turtles were comparatively few; consequently, previous reports of study results tended to focus on more abundant species of fish and invertebrates. Records of underwater sightings of sea turtles were obtained

Table 1. Summary of studies reviewed for records of underwater sightings of sea turtles.

Study	Distance to Land (km)	Depth (m)	Substrate	Sampling Method	Reference
Flower Gardens	191	20 - 30	Coral Reefs	Diver Observation Video Transecting	*1, 2, 3*
Buccaneer Platforms	50	21	Energy Production Platform	Diver Observation	*4*
Northwest Gulf Banks	50 - 150	18 - 70	Hard-Bottom Banks	Diver Observation (from submersible)	*2, 3, 5, 6, 7*
Central Gulf Platforms	5 - 19	12 - 16	Energy Production Platform	Diver Observation	*8*
CSA-a	53 - 138	17 - 30	Hard-Bottom Banks	Diver Observation	*9*
CSA-b	57 - 124	20 - 57*	Energy Production Platform	Diver Observation	*9*
South Texas Platforms	7 - 78	20 - 67*	Energy Production Platform	Diver Observation	*10*
Sebree Bank	44	33	Hard-Bottom Bank	Diver Observation	*10*
Panama City	3	22	Artificial and Natural Reefs	Diver Observation	*11*
Southwest Florida-a	19 - 230	13 - 64*	Instrument Array	Time-Lapse Photography Diver Observation	*12, 13*
Southwest Florida-b	19 - 230	13 - 64*	Hard-Bottom with Sand Veneer	Video Transecting	*12, 13*

1. Boland et al. (1983), 2. Rezak and Bright (1981), 3. McGrail et al. (1982), 4. Gallaway et al. (1981), 5. Bright and Rezak (1976), 6. Bright and Rezak (1978a), 7. Bright and Rezak (1978b), 8. Gallaway et al. (1979), 9. Continental Shelf Associates, Inc. (1982), 10. LGL Ecological Research Associates, Inc. (1982), 11. Chandler et al. (1985; and unpub. data), 12. Danek et al. (1985), 13. Danek and Lewbel (1986).

* Diver Observation to 30 m depth only.

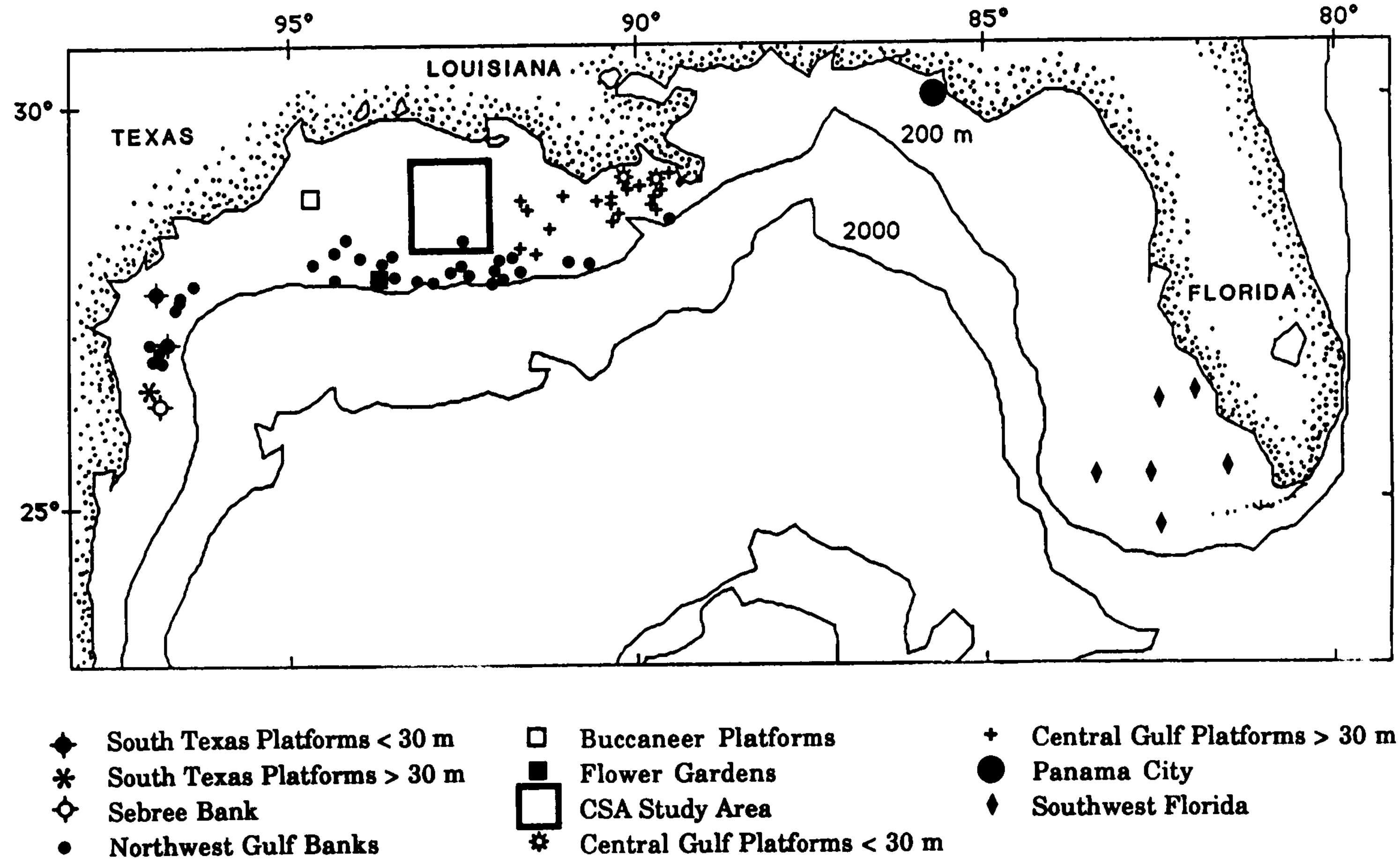

Figure 1. Map showing study area locations in the northern Gulf of Mexico. The Continental Shelf Associates, Inc. (CSA) study area contained 12 banks and 20 platforms. The Flower Garden study contained two sampling stations. All other sampling stations are plotted individually.

from a re-examination of field logs and data tables and interviews with principal investigators.

The first task in reviewing this material was to classify the studies with respect to sampling methods, geographic location, and habitat type. In all, three basic sampling methods were used: direct observations by divers (diver observation), remotely operated video cameras (video transects), and single-frame exposures of an emplaced cine camera (time-lapse photography). Specific details of the application of these methods, particularly the diver observation, differed between studies and are described below. Site descriptions and methods for individual studies are provided in the results section to avoid repetition. The study areas encompassed locations off the coasts of Texas, Louisiana, the Florida panhandle, and southwest Florida (Figure 1). Details of the habitat types are provided in the study area descriptions.

Diver Observation

Application of diver observation as a survey tool differed among the studies with respect to the diving apparatus, the methods used to record sightings, and the constraints on observation imposed by the sampling design of dives. Divers in the Northwest Gulf Banks study used the research submersible DIAPHUS; divers in all other studies used standard scuba apparatus. Scuba dives were conducted by a team of two to four divers, who were limited to a depth of 30 m and a duration of approximately 30 min. The DIAPHUS operated to depths of 150 m for periods of up to 7 h. Sightings were immediately recorded on waterproof slates or data sheets in the Northwest Gulf Banks and Panama City studies. In all other studies, sightings were recorded during debriefing sessions conducted immediately after the divers surfaced.

Three general types of diver observations were distinguished in the reviewed material. These can be summarized as follows:

1. Exploratory Dives: Dives of this type were carried out with scuba gear and with the submersible DIAPHUS. In other respects the objectives of exploratory dives were the same: to survey the range of biota and micro-habitats within a given area. In the Northwest Gulf Banks study, for example, the submersible DIAPHUS followed cross-bank transects (shallow to deep or deep to shallow) within the area of a given bank. The biota observed during the dives were logged on video, photographic, and audio records, as were details of the bottom topography. Exploratory scuba dives were carried out on a variety of energy production platforms and hard-bottom banks to familiarize the researchers with the biota, architecture, and topography of the study sites.

2. Census Dives: These dives were designed to obtain quantitative records of the numbers of megafaunal species within a tightly specified survey area such as the base of an energy platform or along a line-transect across a reef. Unlike the exploratory dives, in which all noteworthy megafauna were recorded, only those turtles that were sighted within the transect or survey area were recorded on census dives.

3. Task-Oriented Dives: These dives were conducted to execute specific tasks related to the overall objectives of the studies. Examples of such tasks include scraping fouling organisms off platform legs, collecting sediment samples, and servicing instruments. During these dives the researchers' attention was focused much more narrowly than was the case in exploratory or census dives. Consequently, their opportunities for sighting megafauna such as sea turtles were diminished.

Video transecting

A portable video system was used in the Flower Gardens and Southwest Florida studies for visual assessment of benthic organisms. The apparatus consisted of two video cameras mounted in parallel on a sled. The sled was lowered from a surface vessel, which then drifted or motored slowly along transects through the study area. Photographed images were simultaneously viewed on a surface video-monitor and recorded on video tape. Altitude above the bottom was maintained by adjusting the winch in response to images viewed on the monitor. No attempt was made to steer the camera toward or away from bottom features. The transects were therefore random samples of benthic biota within pre-selected sampling areas. The paired cameras were used selectively to obtain double images of photographed subjects; the image separation provided a means for accurately estimating transect widths and the total area surveyed.

Time-Lapse Photography

The time-lapse camera system used to obtain data from the Southwest Florida study consisted of a Super-8 mm cine camera, an electronic strobe, and a battery pack contained in separate underwater housings. The camera was loaded with 50-foot rolls of film comprising 3600 frames and was set to take single-frame exposures at one-hour intervals. The usual servicing interval was approximately 90 days. Use of the strobe provided artificial lighting for all exposures. Both the camera and strobe housings were attached near the bottom of instrument arrays (pipe frameworks) measuring 1.5 m on each of four sides and standing approximately 2 m tall (Figure 2). The camera was oriented to photograph the interior of the array and the area approximately 2 m (or the limit of visibility) beyond the edge of the array. The time of day for each frame was calculated from

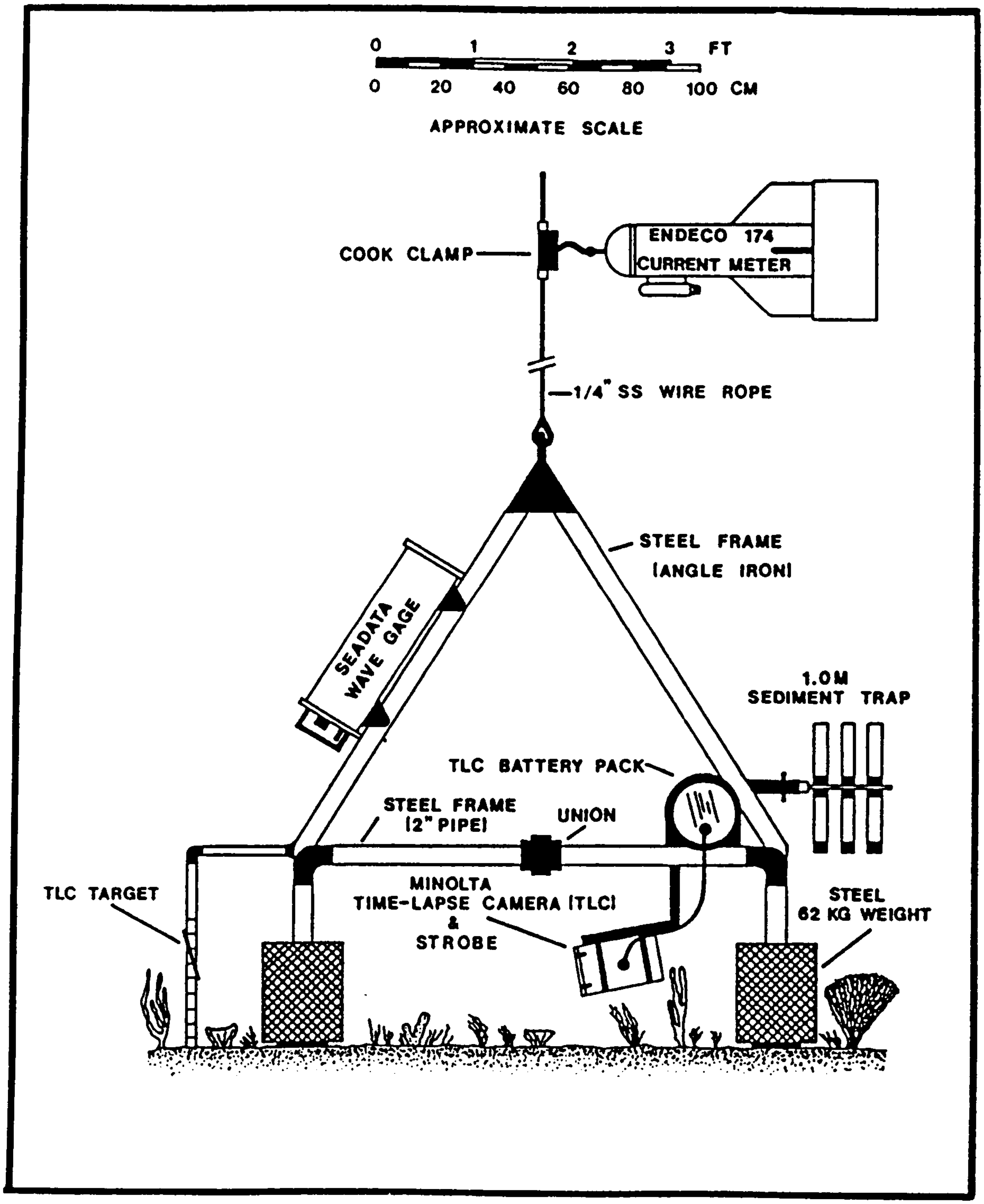

Figure 2. Instrument array deployed during the Southwest Florida study. The majority of turtles sighted were photographed with their forequarters near or under the portion of the framework opposite the camera. After Danek and Lewbel (eds.) 1986.

the start and end times of the film rolls. Diel variation in light level visible in the processed film provided a confirmation of frame-times.

Results

Flower Gardens

The East and West Flower Garden Banks are located approximately 190 km southeast of Galveston, Texas, at approximately 27°55' N by 93°36' W and 27°52' N by 93°49' W, respectively. These two banks are considered to be the northern-most hermatypic-coral reefs in North American waters (Bright et. al., 1985). The East Bank is the smaller of the two with a basal area of approximately 67 km^2. Its crest rises to a depth of 17 m. The West Flower Garden Bank, where all turtle sightings occurred, covers a larger area of about 137 km^2 with the shallowest depth reaching 20 m. The upper coral reef zone which includes live coral areas down to a depth of approximately 40 m, occupies about 0.5 km^2 on the West Bank and about 3 km^2 on the East Bank.

A total of 178 task-oriented dives were carried out during five visits to the Flower Garden study sites between September 1979 and February 1981, 98 at the East Flower Garden site and 80 at the West Flower Garden site (Table 2). In all, 12 turtle sightings were recorded during these samplings, all at the West Flower Garden site. The sightings occurred in the course of successive samplings carried out in February, June, and September of 1980. The sightings were all of a single individual, a loggerhead, with a carapace length of approximately 90 cm. The turtle appeared unafraid and would approach divers closely enough to be touched. It was identified on the basis of a distinctive barnacle pattern on its carapace. A comparison of photographs taken on the June and September samplings confirmed this identification (Figure 3).

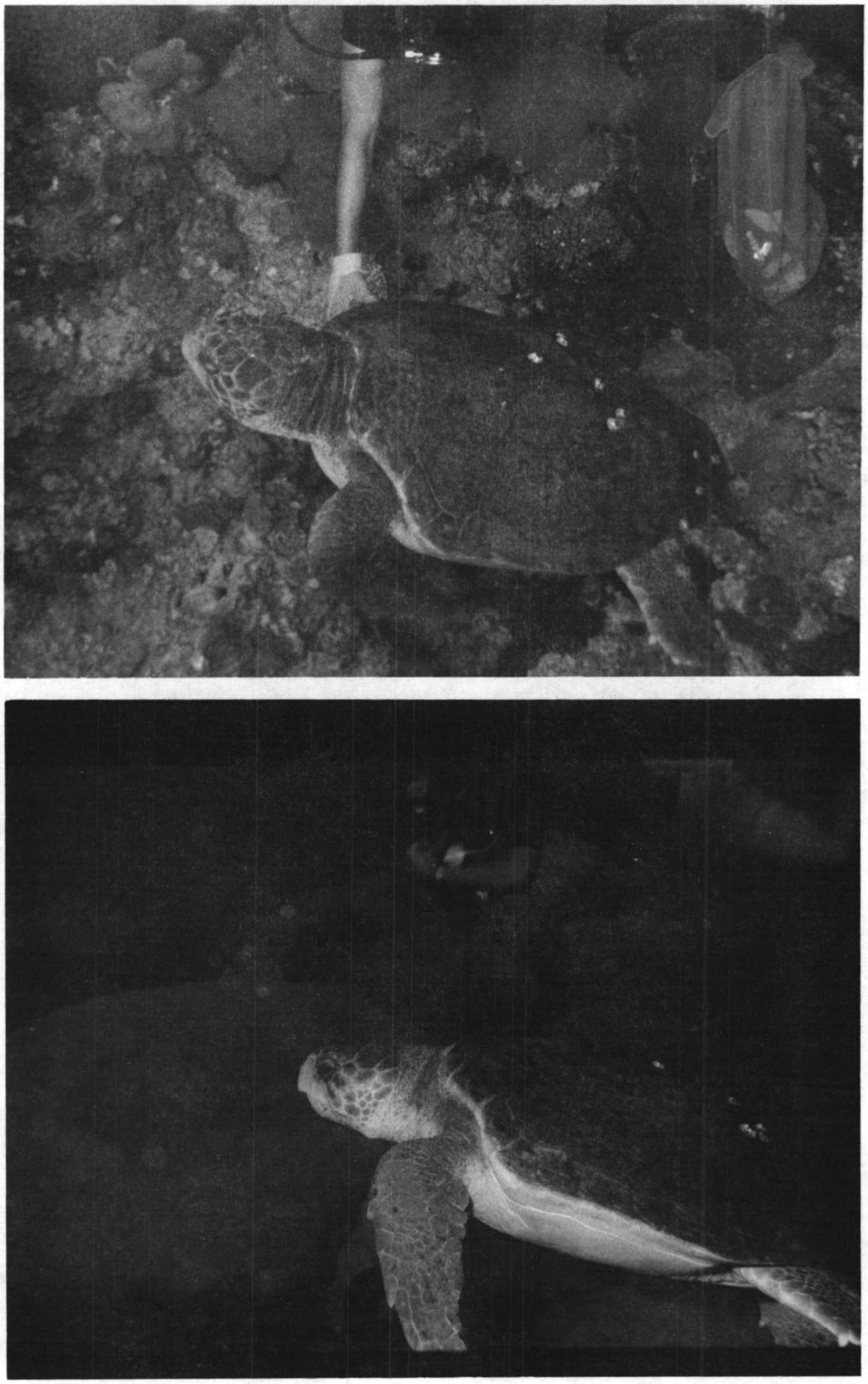

Figure 3. Resident loggerhead turtle photographed at the West Flower Garden sampling station. This individual was readily recognized by the barnacle pattern on its carapace. The animal was first sighted on 19 February 1980; upper photograph was taken on 16 June 1980, lower photograph on 30 September 1980. (Photographs by G.S. Boland)

Table 2. Summary of Flower Garden dives. The dives were primarily task-oriented, generally with one to two exploratory dives at the beginning and end of each sampling period. The sea turtle sightings were all of the same individual and occurred during both task-oriented and exploratory dives.

Date	Stations	Number of Dives	Turtle Sightings
Sep-79	West	19	0
	East	19	0
Feb-80	West	15	2
	East	14	0
Jun-80	West	22	7
	East	24	0
Sep-80	West	21	3
	East	36	0
Feb-81	West	3	0
	East	5	0
Total		178	12

Extensive video transecting at the Flower Garden sites resulted in a total of 357 h of video records that surveyed an estimated area equal to 176.24 ha of reef habitat between October 1980 and October 1982: 42.71 ha in the West Flower Garden site and 133.55 in the East Flower Garden site. Only two sightings of sea turtles were recorded, both at the West Flower Garden. The first turtle was sighted in February 1981 and was identified as the same loggerhead that had been seen by divers. The second turtle was sighted on 14 July 1981; it was also a loggerhead, but was a different individual.

Buccaneer Platforms

The Buccaneer gas and oil field is located approximately 50 km south of Galveston in water depths of approximately 21 m. At the time of the study it comprised 19 structures occupying an area of 59 km^2 in portions of three Federal lease blocks. The two largest structures in the field are production platforms, each measuring approximately 70 by 50 m and supported by 12 legs extending into the bottom. The substrate in the area is composed of poorly sorted sand with low concentrations of silt and clay (Gallaway et al., 1981). Directly below platform structures, the substrate can be composed of high concentrations of components of the fouling community (primarily large clusters of the barnacle Megabalanus antillensis) which have been broken off and settled to the bottom. There have been no reports of major oil spills from this field (Gallaway, 1980).

The underwater structures of the Buccaneer Oil and Gas Production Field were surveyed exhaustively during 599 primarily task-oriented dives conducted during a series of scientific investigations between 9 August 1977 and 7 September 1980. An additional ten exploratory dives were logged between 1981 and 1986 (G.S. Boland, unpublished data). These observations resulted in four sightings of loggerhead sea turtles. Three of these turtle sightings were similar in nature. They were all made during daylight hours in the month of August and the turtles were seen swimming above the bottom near or inside the legs of a platform. The other sighting was made in September at night, and the turtle was observed on the bottom next to a platform leg.

Northwest Gulf Banks

Rezak et. al. (1985) reported the summary of all biota observed during all topographic features projects funded by the Bureau of Land Management (BLM) between 1975 and 1983. Thirty-five banks in the northwestern Gulf of Mexico were divided into five categories as follows: 1) Mid-shelf Claystone/Siltstone; 2) Flower Gardens; 3) Outer Shelf Edge Banks; 4) Transitional Mid-shelf Banks, and 5) South Texas Mid-shelf Banks. Sea turtles were included in the list of organisms derived from five topographic features study final project reports between 1975 and 1983.

Investigators in this study completed a total of 373.6 h of exploratory diving with the submersible DIAPHUS and 40 h of video transecting (transect areas or distances could not be calculated from the available data). The observations were carried out at 30 individual hard-bottom sites within five bank groups (Table 3). These observations resulted in one underwater sighting of a sea turtle. This individual, a loggerhead, was sighted and photographed on 28 August 1977 swimming at a depth of 50 m over a hard-bottom feature named "18 Fathom Bank", which is located at approximately 27° 58' N by 92° 36' W. This sighting was the deepest from any of the studies presented here.

Central Gulf Platforms

This study was conducted on energy production platforms located in the north-central Gulf of Mexico (Gallaway et al., 1979). Brief exploratory dives were conducted at 20 platforms; four of these were designated as primary study sites (Figure 1) and were revisited for census dives and sample collection. Two of the primary platforms and nine of the secondary platforms were in depths less than 30 m and were inspected to the bottom. A total of 21 exploratory dives were carried out on the primary platforms. These observations resulted in no sightings of sea turtles.

Table 3. Summary of Northwest Banks study diver observations and video transects. Submersible observations were all conducted from the DIAPHUS and video observations were made from a video system suspended to the bottom from a surface research vessel. Depths ranged from 25 to 75 m. The single loggerhead sea turtle sighting occurred at 18 Fathom Bank during the summer of 1977.

Bank Group	Number of Banks	Years Sampled	Submersible Hours	Video Hours
Mid Shelf Claystone/Siltstone	3	1976-77	18.8	0.0
Flower Gardens	2	1975-78	181.6	17.0
Outer Shelf Edge Banks	13	1976-78	97.4	0.0
Transitional Mid-Shelf	2	1978	19.0*	0.0
South Texas Mid-Shelf	10	1975-76	56.8	23.0
Total	30		373.6	40.0

* The single recorded turtle sighting occurred here.

Continental Shelf Associates, Inc. (CSA)

Exploratory dives were conducted at 12 hard-bottom features and 13 platforms on the continental shelf south of Louisiana (Continental Shelf Associates, Inc., 1982). Seven of the platforms were in water depths of less than 30 m and were surveyed to the bottom; the remainder were surveyed to depths of 30 m only. All of the hard-bottom areas crested at depths of 30 m or less. These observations resulted in no sightings of sea turtles.

South Texas Platforms and Sebree Bank

Exploratory dives were conducted at three energy production platforms and one hard-bottom feature off the south Texas coast (LGL Ecological Research Associates, Inc., 1982). The platforms were situated 7.2, 12.7, and 74.4 km from shore at depths of 20, 23, and 67 m, respectively. Visibility was severely limited at the shallowest station, was improved at the next deepest station, and exceeded 30 m at the deep-water station. Sebree Bank is located at 26° 25' N by 96° 58' W and crests at a depth of 33 m. This feature is composed of sediment-laden rocky outcrops and harbors epifauna typical of near-shore live-bottom areas, including ahermatypic corals (Oculina and Phyllangia), bryozoans, sponges, and hydroids. Two exploratory dives were carried out at each of three energy production platforms and at Sebree Bank. One hour of video transecting was also performed at Sebree Bank. These observations resulted in no sightings of sea turtles.

Panama City

Census dives were conducted by a team of two divers at 12 artificial reefs and an offshore platform near Panama City, Florida (Chandler et al., 1985, and unpublished data). The artificial reefs included six barges and six areas of piled waste material ranging from concrete culverts to scrapped jet fighters (Table 4). The offshore platform was the Stage II structure operated by the U.S. Navy at a depth of 15 m. All the artificial reefs had well-established biofouling communities except for the PCMI Barge which was deployed during this study.

The Panama City study completed 194 census dives that surveyed a total of 3014.4 m^2 of artificial reef habitat; these observations resulted in 17 sightings of sea turtles (Table 4). All turtles sighted were loggerheads and all were recorded within 1 m-wide line-transects across the reefs. The greatest number of sightings (eight) occurred at the Offshore Twin Barge artifical reef. These animals were usually observed at rest in a shallow pit in the sand at a place were the barge formed a sheltering overhang. No photographs exist to show whether individuals were sighted repeatedly.

Table 4. Summary of Panama City study diver observations. All diver observations were conducted as census dives.

Station (name describes substrate)	Depth (m)	Number of Dives	Area Surveyed (sq. m)	Number of Turtle Sightings
Stage II Platform	15	14	213.5	0
Loss Pontoon (junk)	18	12	183.0	0
Holland Barge	21	13	198.3	0
Joe Smith Barge	21	6	91.5	0
Inshore Twin Barge	22	43	467.3	1
Offshore Twin Barge	22	40	427.2	8
Midway (junk)	23	10	152.5	1
Blown-up Barge	20	14	213.5	1
Warsaw Site (junk)	23	23	350.8	0
PCMI Barge	21	19	289.8	2
Fontainebleu Site (junk)	23	10	152.5	3
Deep Barge	29	2	30.5	0
Stage I Site (junk)	29	4	244.0	1
Total		194	3014.4	17

Southwest Florida

The six sampling stations shown in Figure 1 were located on the continental shelf off southwestern Florida. In this region, the shelf is a broad (200 km), generally flat platform of limestone that slopes gently to the west throughout the study area (Danek and Lewbel, 1986). The hard substrate is alternately exposed or covered with a thin veneer of coarse, primarily calcareous sand. An instrument array (Figure 2) was deployed at each of the six sampling stations. The array at Station 52 remained in place during the entire length of the study (9 December 1983 to 11 December 1985); arrays at the remaining five stations were removed periodically for servicing or repair. Time-lapse cameras were deployed on these arrays for varying intervals during the study and were set to take photographs at hourly intervals. Discounting photographs obscured by water turbidity, a total of 25,186 usable photographs was obtained from the six cameras; this material included 231 photographs of sea turtles (Table 5). Video transects were completed in the vicinity of the arrays during each visit to the stations (Table 6). Analysis of the video records provided a detailed description of the biotic and abiotic characteristics of the benthic environment at each station; however, no sea turtles were sighted in any of the video records. Additional underwater observations consisted of 53 task-oriented dives conducted to service the cameras, sediment traps, and other components of the instrument arrays. The dives resulted in one sighting at Station 7.

The six sampling stations differed with respect to depth, distance from shore (see Table 5), and the presence of sessile benthic organisms. Station 52, where the majority of turtles were photographed with the time-lapse camera, was a shallow (13 m), low-relief area dominated by patches of algae (21% cover), sponges (8% cover), and very dense stands of Gorgonacea colonies (over 28,000 per ha). Large sponges (up to 0.5 m height) such as Ircinia campana were prominent benthic features. A comparison of the six stations with respect to depth and density of gorgonians (Figure 4) showed Station 52 to be distinct from the remaining five stations. Station 55, which had a density of gorgonians comparable to Station 52, was about twice as deep. Station 44, which was at the same depth as Station 52,

Table 5. Summary of Southwest Florida study time-lapse photographs by station.

Station	Latitude (N)	Longitude (W)	Distance to Land (km)	Depth (m)	No. of Hourly Photographs	No. of Turtle Photographs
44	26° 17.7'	82° 12.7'	15	13	810	10
52	25° 17.5'	81° 39.8'	50	13	6,749	211
55	24° 36.2'	82° 42.0'	165*	27	6,213	3
7	26° 17.0'	82° 43.7'	60	32	6,481	7
21	25° 17.3'	82° 52.1'	130	47	3,902	0
23	25° 16.9'	83° 37.8'	200	74	1,031	0
Total					25,186	231

*To mainland; Station 55 was 90 km from Key West.

Table 6. Summary of Southwest Florida video transect coverage in hours. All transects were made within 0.7 km of time-lapse instrument arrays. No turtle sightings were recorded.

			Station					
Cruise	21	52	23	7	44	55	Other	Total
Winter 83		3.15			2.65			5.8
Spring 84	5.65	2.75	5.36		2.75		14.5	31.01
Summer 84	2.63	2.33	2.31				25.71	32.98
Winter 84	2.43	1.45	2.9	2.55		1.33	16.86	27.52
Spring 85	1.75	1.55	2.98	1.3		1.12	7.64	16.34
Summer 85	2.73	2.57	1.92	3.1		1.18	3.46	14.96
Fall 85	1.08	2.27		1		1.1	4.07	9.52
Total	16.27	16.07	15.47	7.95	5.4	4.73	72.24	138.13

was characterized by a density of gorgonians about two orders of magnitude less.

The time-lapse cameras were directed toward the bottom opposite the camera mounting (Figure 2) and took in a visual frame approximately 2 m wide by 3 m deep. Artificial light provided by the strobe was sufficient to illuminate the photographed area at all hours. Although there was a perceptible change in the light level between day and night photographs, there was no difference in the

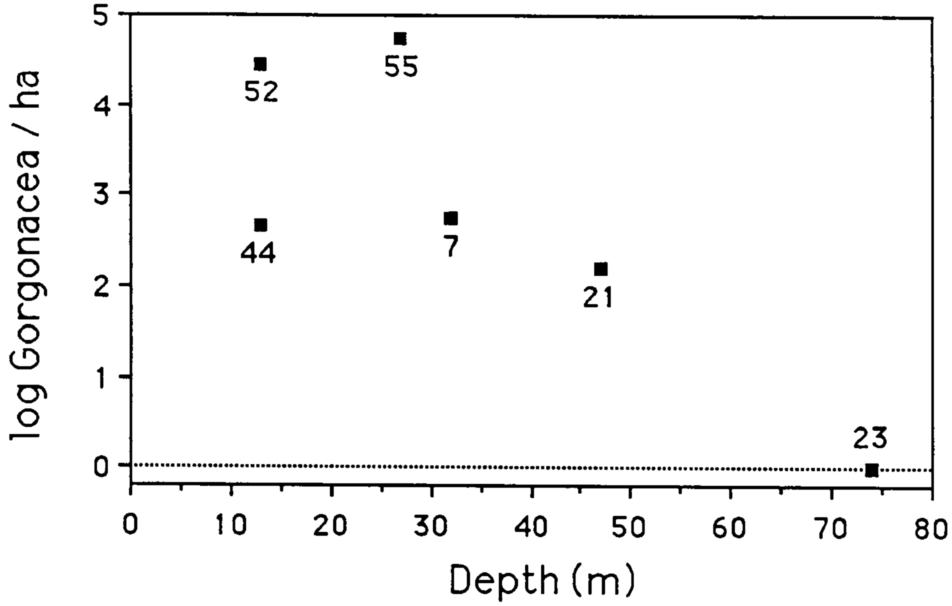

Figure 4. Comparison of the Southwest Florida study sampling stations plotted with respect to their depth and the density of gorgonians in the area of the stations. The density of gorgonians was computed by counting the numbers of Gorgonacea per ha in the video transects taken at each station.

clarity of the images. The background was occasionally obscured when large fish were photographed directly in front of the camera lens. A more serious loss of clarity was caused by high water turbidity during storms, which sometimes interrupted viewing for periods of several days. Several of the records analyzed for these results included only those photographs in which the strobe and camera functioned properly and the water clarity was sufficient for distinguishing the bottom and the camera target. Photographs in which these conditions were met, but the view was partly or entirely blocked by a large fish were included in the data record.

Turtles were photographed as they swam past the field of view, rested on the bottom within the frame, or pressed against the array structure. Except for occasions when camera alignment was shifted by colliding turtles or large fish, the cameras remained rigidly fixed and clearly showed the movement of animals between the hourly exposures. Rarely did a photograph show a full view of a turtle; profile shots of the head and foreflippers were sometimes seen; most commonly, however, turtle photographs showed only a portion of the carapace taken as the animal lay on the bottom directly in front of the camera and at least partially within the framework of the array. Although there were numerous hourly sequences of two or even three successive photographs showing turtles within the array, the photographs always indicated some movement between exposures. There was therefore no evidence that the turtles were dormant at the arrays for periods of more than an hour.

Identification of turtles to species from the photographs was problematic because of the fragmentary views provided by the obliquely angled camera. Loggerheads, the most commonly identified species, were distinguished on the basis of their head and neck shapes and scute patterns; three photographs of leatherbacks were identified by their characteristic carapace ridges; and a Kemp's ridley was identified in a full carapace view that clearly showed the scute pattern and characteristic rounded shape. In the majority of cases, however, it was not possible to speciate the turtles from the fragments of carapaces that appeared in the photographs. It was occasionally possible to identify individual turtles that reappeared in successive photographs taken during a single deployment of the time-lapse camera. These animals were recognized on the basis of scute patterns, size, and patterns of fouling organisms. Fragmentary views of turtles in the photographs, such as the end of a flipper or the edge of a carapace, could not be identified as specific individuals; such recognition was achieved with complete confidence only when a close sequence of photographs showed similar views of a turtle. On this basis, at least six individual turtles were identified among the 211 photographs from Station 52. Intensive review of this material left the strong subjective impression that the majority of photographs were of a single individual.

The distribution of turtle photographs from Station 52 showed a distinct diel pattern (Figure 5). From a total of 211 sightings, the mean number of sightings per hour among 13 hours of daylight (0700 to 1900 h) was 4.2 (standard deviation 2.12); while the mean number of sightings per hour among 11 hours of darkness (2000 to 0600 h) was 14.1 (standard deviation 2.74). A t-test of difference between these means was significant (p = 0.001). A similar pattern was also observed among the sightings from the other three arrays where turtles were sighted.

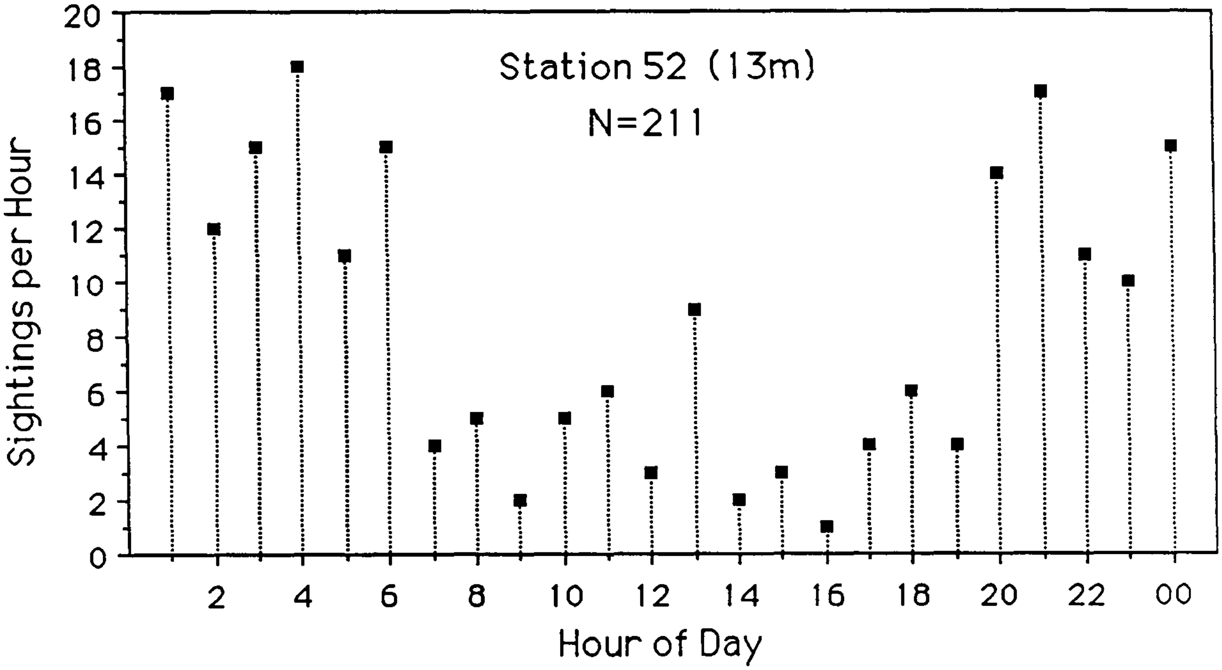

Figure 5. The diel distribution of turtle sightings among the time-lapse photographs from Station 52 of the Southwest Florida study.

The numbers of turtle sightings at Station 52 increased markedly during the two years that the array was deployed (Table 7). The numbers of sightings per day were calculated on a monthly basis, where the data allowed, to show changes over time. A plot of these means shows a distinct trend of increase during the study period (Figure 6). A comparison of the number of sightings during hours of daylight and darkness shows that the increase was largely due to greater numbers of sightings during darkness (Figure 7).

Table 7. Monthly sampling effort with the time-lapse camera at Station 52 of the Southwest Florida study. Periods of high turbidity were deleted from the record.

Year	Month	Number of Hourly Photographs	Number of Turtle Photographs
1983	December	535	0
1984	January	439	2
	March	198	2
	August	365	5
	September	465	1
	December	612	9
1985	January	179	2
	March	32	3
	April	142	7
	June	124	9
	July	700	23
	August	744	20
	September	717	49
	October	666	43
	November	567	23
	December	264	13
Total		6749	211

To test the validity of these trends, it was assumed that the number of days on which the array was occupied at least once during a 24 h period was distributed

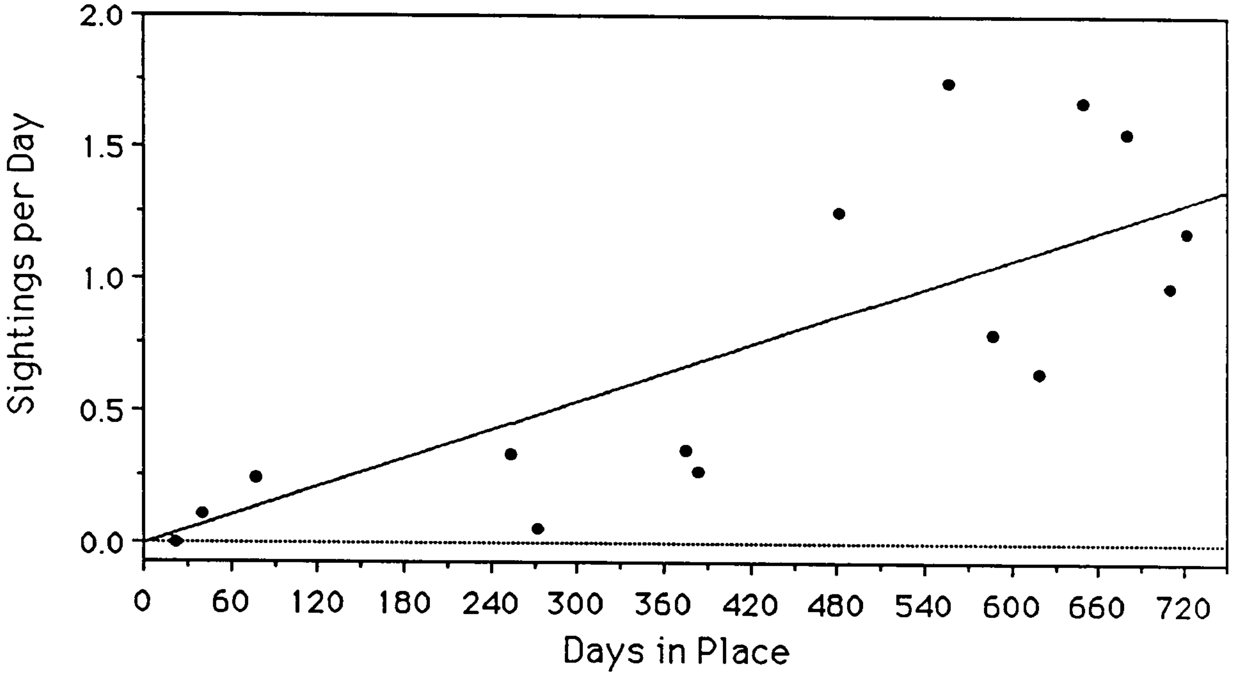

Figure 6. The numbers of turtle photographs per 24 h at Station 52 of the Southwest Florida study. Days in place indicates the total deployment interval of the instrument array. Sightings per day were calculated for each month or portion thereof during the study.

as a Poisson random variable with rate λ during each sampled month or portion of a month, and that this rate remained constant within months. Under the assumption of a Poisson distribution, the estimate of the rate of occupation is

$$\lambda = n/T$$

where n is the number of days that the array was occupied and T is the number of days sampled (Bhat, 1984). The probability of occupation is then distributed

$$e^{-\lambda} \lambda^{T} / T! .$$

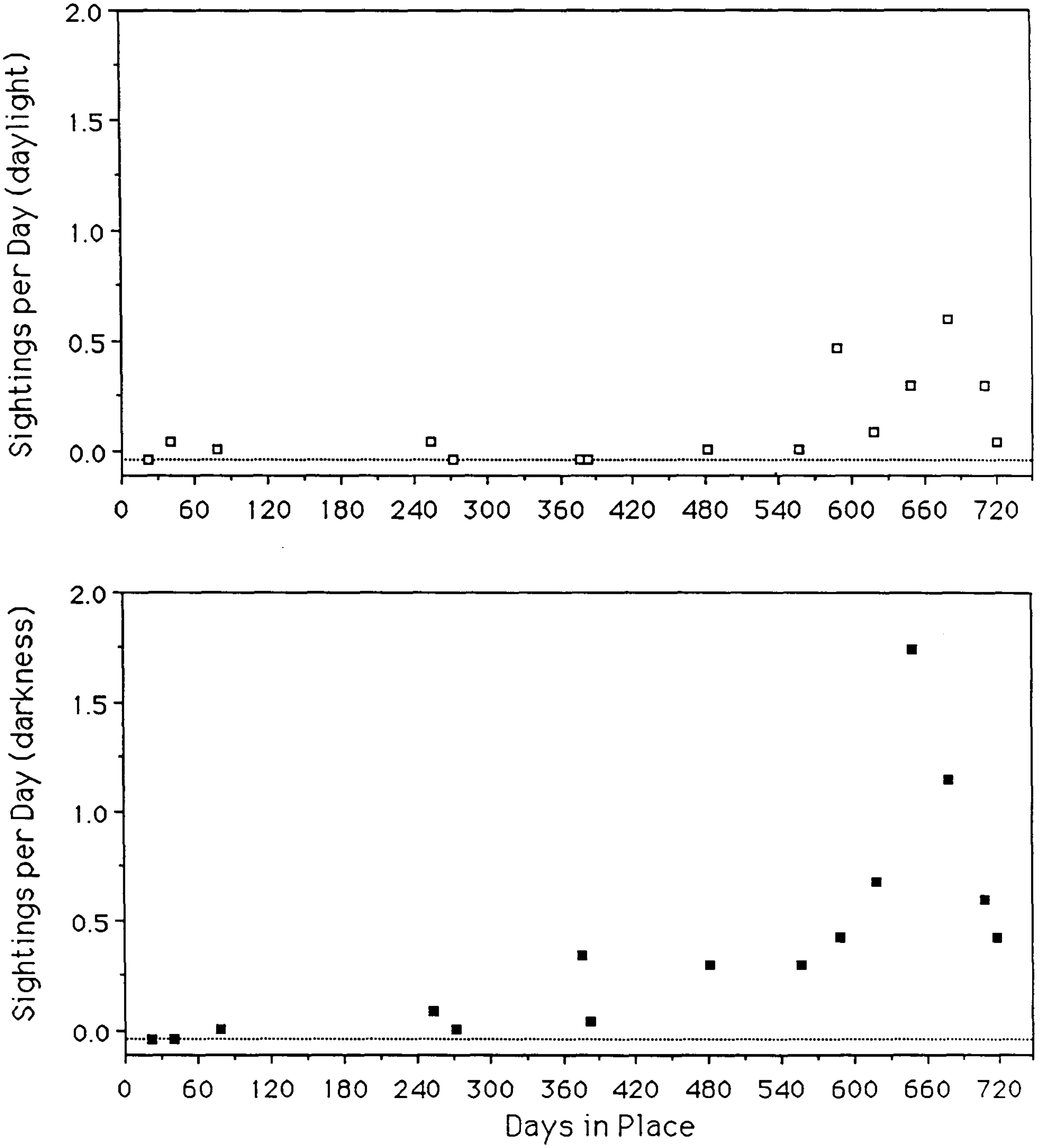

Figure 7. Numbers of sea turtle sightings per 24 h at Station 52 of the Southwest Florida study. Rates are shown as sightings during daylight (upper) and sightings during darkness (lower).

By accruing the rates on a daily, rather than an hourly basis, the different probabilities for success between sampling during darkness and daylight were given equal weight (Figure 8). The monthly sightings were pooled so as to estimate daily occupation rates for 12 periods of at least 10 days or longer (Table 8).

The likelihood-ratios of these rates were then used to test the null hypothesis: all daily occupation rates were the same (Rohatgi, 1976). The result of this test was rejection of the null hypothesis at the 0.001 level of significance. Further paired comparisons of the 12 occupation rates are arranged chronologically in Table 8. These comparisons show, at the 0.025 significance level, a daily occupation rate that increased throughout the study period The maximum occupation rate of one or more sightings per day occurred during the 12 days of observations between March and June, 1985.

The daily records of sightings were then compiled (Figure 8) to determine the expected number of sightings per day of occupation. The mean was 1.85; standard error was 2.018. The number of sightings per day may be taken as an estimate of the amount of time that a turtle spent at the array during a day in which it was seen at least once. This representation of the utilization of the array by turtles suggests that the daily occupation rate increased significantly over time as the array remained in place, while the time spent at the array per day of occupation was a constant function of turtle behavior. That is, if a turtle comes to a structure on a given day, it will remain there for some period of time, interrupted possibly by periods of foraging and trips to the surface to breathe. As the structure remains in place, however, it will acquire fouling growth, attract fish and invertebrates, and gradually become a more attractive habitat for turtles; and the probability of occupation on a given day will increase.

Table 8. Multiple comparison of daily occupation rates during 12 observation intervals. During a total of 273 complete days of observation there were 111 days during which at least one turtle photograph was taken, for an overall daily occupation rate of 0.406. Paired comparisons were performed sequentially, beginning with the greatest occupation rate, e.g., A with B, A with C, B with C, B with D, etc. The results are arranged chronologically. Observation intervals whose letters do not overlap could not be shown to be the same at a significance level of 0.025.

		Number of Days Observed											
		22	19	15	19	33	12	31	31	29	28	23	11
		Observation Interval											
Occupation Rate		10-Dec-83 31-Dec	1-Jan 19-Jan	17-Aug 31-Aug	1-Sep 19-Sep	6-Dec 7-Jan	31-Mar 30-Jun	1-Jul 31-Jul	1-Aug 31-Aug	1-Sep 30-Sep	1-Oct 31-Oct	1-Nov 30-Nov	1-Dec 11-Dec-85
A.	1.000						A						
B.	0.700						A						B
C.	0.679						A				C		B
D.	0.621						A			D	C		B
E.	0.565						A			D	C	E	B
F.	0.484						A	F		D	C	E	B
G.	0.452						A	F	G	D	C	E	B
H.	0.242					H		F	G	D		E	B
I.	0.200			I		H		F	G	D			B
J.	0.053		J	I		H							
K.	0.053		J	I	K								
L.	0	L	J		K								

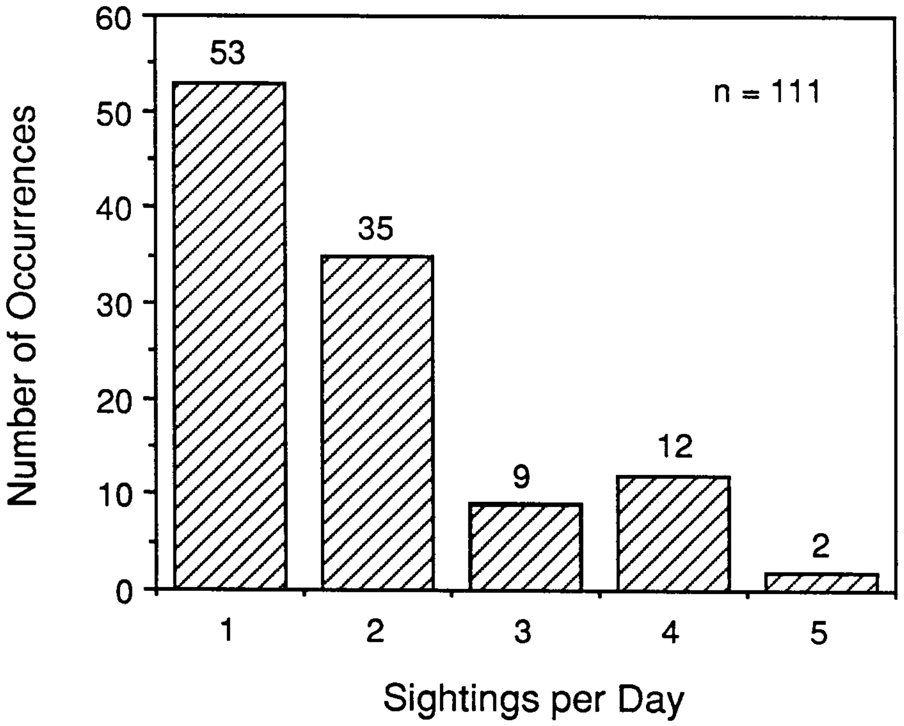

Figure 8. Distribution of residency times. Values signify the number of times when a given number of hourly sightings were obtained during a full day.

Discussion

This review of scientific records, while not exhaustive, comprised a major portion of the research diving and underwater observation conducted in the Gulf of Mexico during the past 10 years. A summary of the sampling effort (Table 9) shows that these studies represent a substantial body of observations: approximately 1024 scuba dives, 495 hours of video transecting, 374 hours of submersible dives, and 1545 days of time-lapse photographic observation, which were conducted by trained observers who maintained accurate records. The observations were conducted in a variety of habitats, including sites of natural relief and artificial structures, as well as areas of flat and featureless bottom.

Although the Mississippi and Alabama coastal regions were not surveyed, the studies encompass a wide geographic range within the northern Gulf of Mexico. This effort has yielded 268 verifiable sightings of sea turtles underwater.

Table 9. Summary of all sampling effort and numbers of sea turtle sightings during both limited (A) and intensive (B) programs of underwater observation.

A. Limited Studies: approximately two dives per site.

Study Name	Banks	Platforms (< 30 m)	Platforms (> 30 m)	Turtle Sightings
CSA	12	13	7	0
South Texas Platforms and Sebree Bank	1	3	2	0
Central Gulf Platforms	-	20	11	0
Total	13	36	20	0

B. Intensive Studies: repeated sampling at each site

Study Name	Sampling Methods	No. of Stations	Sampling Effort	Turtle Sightings
Southwest Florida	Video Transecting	12	138 h	0
	Diver Observation	4	53 dives	1
	Time-lapse	6	25186 frames	231
Flower Gardens	Video Transecting	2	357 h	2
	Diver Observation	2	178 dives	12
Panama City	Diver Observation	13	194 dives	17
Buccaneer Platforms	Diver Observation	6	599 dives	4
Northwest Gulf Banks	Submersible Obs.	32	374 h	1
	Video Transecting	11	40 h	0
Total		88		268

Although it was not possible to compare precisely the results of these very diverse studies, differences in the success rate achieved in separate regions, by use of different observation techniques, and over different substrates can be examined. Sightings from the time-lapse photography contributed 86% of the sightings. The majority of the diver observations and video transects were conducted off the Texas and Louisiana coasts, but nearly half (46%) of the sightings recorded from these methods were from Florida waters. However, the Texas and Louisiana results included numerous task-oriented dives made on energy platforms. Only four sightings could be documented from the nearly 600 dives conducted at platforms. The narrow focus of the divers' attention, particularly under the poor visibility conditions that often prevailed at the platforms, undoubtedly reduced the probability of sightings. The Flower Gardens and Panama City studies were both under good visibility conditions and produced similar numbers of turtle sightings. A combination of exploratory and census dives resulted in turtle sightings on 7% of Flower Garden dives and 9% of Panama City dives. However, the area surveyed by divers in the Panama City study (15.25 or 13.35 m^2 per dive) was very small in comparison to the area observed at the Flower Gardens and the Panama City data do not include numerous turtles sighted outside the survey transects (C.R. Chandler, pers. comm.)

It was clear from these results that sightings of sea turtles underwater occurred with relative infrequency, especially on natural reefs. This was consistent with the findings of Fuller and Tapan (1986) based on anecdotal reports from sport and commercial divers in Louisiana. Factors contributing to the paucity of sightings probably include the limited visibility conditions prevalent in much of the northern Gulf, and the tendency of task-oriented divers to focus their attention on the task at hand. Another factor may be the diel pattern of turtle behavior. The time-lapse photographic data indicated that turtles are most likely to be near structures during the hours of darkness, when diving activities are at a minimum (Figure 5). Interestingly, surface sightings data (Fritts et al., 1983), which were naturally limited to daylight hours, generally showed an increase in midday hours and decreases toward morning and night. Normal daylight activities may therefore tend to take turtles away from structures at the times when most diving takes place.

Other methods, such as aerial surveys (Fritts et al., 1983) and analysis of strandings data (Rabalais and Rabalais, 1980), have produced more substantial data concerning the population numbers and distribution. Given the high cost of diver operations and the infrequency of sightings, surveys by divers or video transecting does not appear to be an effective method for estimating turtle population levels. The paucity of diver-observation sightings made at Southwest Florida stations, where turtles were repeatedly photographed with the time-lapse cameras, raises serious doubts as to whether diver observations can reliably determine if turtles are present at a given site or structure. Because information on sea turtle behavior has been based almost entirely upon sightings from nesting beaches (Carr, 1982), a more appropriate use of diver observation would be to provide anecdotal behavioral data from the underwater habitats.

In this regard, the diver observations described here have provided confirmation of long-term fidelity of turtles to localized sites and demonstrated some of the ways in which turtles may utilize natural or artificial structures. The precision with which residency time and habitat utilization were specified was determined by the observation methods. The loggerhead seen and identified during the Flower Garden study was a free-swimming animal. Opportunistic sightings during exploratory dives estimated the ambit of its activity as a large portion of the reef complex at the West Flower Garden sampling station, and its residency there as at least four months. The Panama City study utilized repeated census dives that followed fixed transects. In this case, it was possible to observe repeatedly that individual turtles rested on the bottom under specific portions of artificial structures. The turtle sightings at Buccaneer platforms were consistent with the Panama City sightings; two of the four sightings were animals that were resting on the bottom in direct contact with one of the legs of the platform. However, because dives were of limited duration and were conducted at irregular intervals, diel variation and long-term residency rates could not be estimated.

The time-lapse photographs showed that artificial structures of modest size may be repeatedly visited by turtles. Comparing results of video surveys and time-lapse from the Southwest Florida study (Tables 5 and 6) suggests that the arrays attract turtles to some degree. However, the very different numbers of sightings at the six arrays (Table 5) indicated that turtle recruitment is not an automatic function of installing structures on the bottom. These results indicated that some areas had more turtles than others; the results from Southwest Florida suggested that depth and the amount of live-bottom cover were important factors for determining the numbers of turtles in an area (Figure 4). At the southwest Florida sites, no turtles were sighted below a depth of 32 m.

The presence of sea turtles in the vicinity of an array was detected because they used the structure that it provided. Data from the array at Station 52, which remained in place continuously for two years, indicated that use of a new structure will increase over time. Two time-dependent processes can be invoked to explain this:

1. The accretion of fouling organisms and the growth of a reef-like community around the structure will increase its attractiveness for turtles.

2. An increasing number of turtles will encounter the array and learn its location.

Because these are contemporaneous processes, neither can be rejected on the basis of the current data. The social behavior of turtles could also be considered as a factor influencing their use of underwater structures, particularly in terms such as competition for structure and home range. Study of such behavior would require being able to identify individual turtles with greater reliability than was possible with the study design described in this report.

Interpretation of the time-lapse material depends upon the assumptions that are made regarding turtle behavior. Some critical details in the photograph can be integrated into these assumptions. Although more than one individual could be identified in the photographs, at no time did two individuals appear in the same photograph. Large jewfish (Epinephelus itajara) were also photographed within the array, but turtles and jewfish were never seen together. Thus, the arrays appear to have been usable by one turtle at a time. Turtles in the photographs were on the bottom rather than swimming. When photographed, they were generally at least partly within the confined space of the array, often in direct contact with the structure. The utility of this behavior may be as a defense mechanism or an energy-efficient method of maintaining stability on the bottom. Similar behavior has been repeatedly observed in captive Kemp's ridleys, which will thrust their heads or flippers into any confining structure and remain motionless on the bottom for up to three hours (E.F. Klima and C.T. Fontaine, pers. comm.).

From this, it is reasonable to assume that each photograph represented some period of residency at the arrays rather than a fleeting glimpse of a swimming turtle. Successive hourly photographs of the same turtle indicated that the residency sometimes lasted for two to three hours or longer. It would also have been possible for a turtle to be at an array without being photographed. If one makes the conservative assumption that each photograph represents one hour of residency, the distribution of sightings per day (Figure 8) would suggest a mean total residency period of 1.85 hours per day. At a daily occupation rate of 0.7 , the rate observed after two years (Table 8), the expected daily residency period would be 1.3 hours per day. The diel pattern indicates that most of the residency would take place at night. This interpretation of the time-lapse data makes minimal assumptions regarding turtle behavior. Additional study could provide further information regarding differences between daytime and nighttime activity and changes in this activity at structures that have been in place for varying periods of time.

The overwhelming majority of sightings were of loggerhead turtles. This is consistent with other sightings data (Fritts et al., 1983; Fuller and Tapan, 1986). Difficulty in identification of species and individual animals in the time-lapse photographs was largely caused by the acute camera angle. Results of the time-lapse observations would have been improved by higher placement of the camera. Taking a single photograph per hour was largely an economy measure that reduced the maintenance overhead. A higher sampling rate would have improved the estimate of residency time obtained from the data. In general, this review suggests that time-lapse sampling could provide a useful and cost-effective means for studying diel patterns, recruitment residency and behavior of sea turtles at natural and artificial structures. Routine time-lapse photography of offshore structures prior to removal could detect resident sea turtles and reduce risks of mortalities.

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March 3, 1849

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