OCS Study
MMS 90-0025

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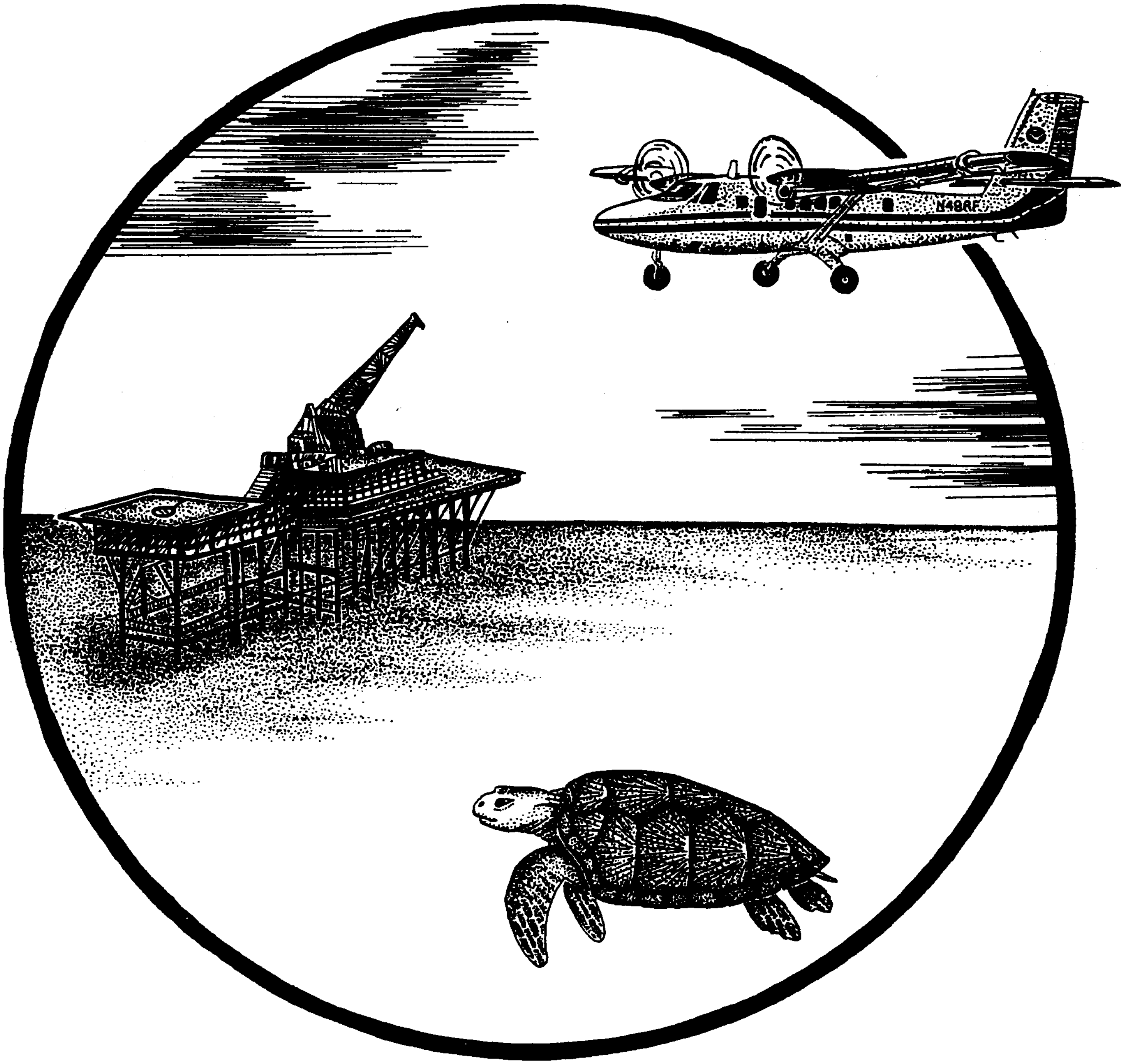

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Association of Sea Turtles with Petroleum Platforms in the North-Central Gulf of Mexico

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ABSTRACT

In 1988 there were over 4,500 petroleum platforms in the north-central Gulf of Mexico. Once a platform is no longer used for petroleum production, federal regulations require that the platform be removed. For platform removals, explosives are commonly used to sever pilings that anchor the platform to the bottom. The use of explosives has the potential to kill or injure marine animals, including sea turtles, in the vicinity of the platform. The five species of sea turtles which occur in the Gulf of Mexico are listed as either threatened or endangered under the provisions of the Endangered Species Act of 1973. The five species are as follows: loggerhead (Caretta caretta), leatherback (Dermochelys coriacea), green sea turtle (Chelonia mydas), Kemp's ridley (Lepidochelys kempi) and hawksbill (Eretmochelys imbricata).

Anecdotal evidence indicated that at least some individual sea turtles, primarily loggerheads, were commonly found in the vicinity of specific platforms. However, the general relationship of the sea turtle population to petroleum platforms was unknown. From June 1988 through June 1990, we used aerial surveys to estimate sea turtle abundance and to study the spatial relationship between sea turtles sighted near the surface of the water and petroleum platforms. We surveyed seven study areas which sampled the range of water depths (3-200 m) in the oil and gas fields offshore of Louisiana. For each study area we used three types of statistical procedures (Hamill and Wright's method, Kendall's rank correlation and chi-square analysis) to test the null hypothesis: Surfaced sea turtles were randomly located with respect to platform locations. We used line transect methods to estimate sea turtle density for each study area.

During the study, we sighted 316 chelonid sea turtles of which we estimated 92% were loggerheads. Most of the sea turtles (78%) were sighted just northeast of the Mississippi River delta in two study areas offshore of Breton and Chandeleur Islands, Louisiana. Sea turtles were present throughout the year but fewer sea turtles were sighted during the coldest months (January and February). East of the river, sea turtle densities were seasonally variable, ranging from 0.92 sea turtles/100 km^2 in winter to 4.83 sea turtles/100 km^2 in spring. Because of the small number of sea turtles sighted in the five study areas west of the river, seasonal density estimates were not made. However, the annual densities in these areas ranged from 0.50 sea turtles/100 km^2 in 13-48 m water depths to 0.11 sea turtles/100 km^2 in 60-120 m water depths. Rather than leaving the north-central Gulf of Mexico in winter, we believe some sea turtles may have brumated or moved to slightly deeper water during cold weather periods. We saw mud trails coming off some loggerheads. These mud trails indicate that they had been brumating by partially burying in bottom sediments. West of the river, sightings of sea

turtles in deeper water areas increased slightly in winter. However, this was not observed east of the river.

East of the river, all three statistical tests indicated that, except during winter, offshore of Chandeleur and Breton Islands, sea turtles were positively associated with platform locations (i.e., generally closer to platforms than expected). In winter, sea turtles were randomly located with respect to platform locations. In the study areas west of the river, sea turtles were randomly located with respect to platforms locations. Before the explosive removal of a platform can proceed, current mitigation measures require that no sea turtle can be sighted within 1,000 m of the platform. East of the river, based on the density of sea turtles (corrected for subsurface turtles) and the observed distance distribution of sea turtles to platforms, we estimated the probability of one or more chelonid sea turtles being within 1,000 m of any platform selected at random was great, generally more than 60%. West of the river, depending on the study area, we estimated that this probability ranged from 2-7%.

We identified 18 petroleum platforms which may have had one or more positively associated chelonid sea turtles at some time during the study. To understand why sea turtles were associated with these 18 platforms, we compared them to other platforms using nine platform characterization variables. Overall, the platforms with associated sea turtles tended to be smaller unmanned platforms that were closer to shore than the other platforms.

Offshore of Breton and Chandeleur Islands, we found chelonid sea turtles preferred more shallow water (generally <20 m) over sandy bottom sediments. West of the river, we did not detect a sea turtle preference for bottom sediments but most were in waters less than 50 m deep.

In addition to shallow water (<200 m) sea turtle studies, we also surveyed deep Gulf waters (>200 m) for cetaceans from July 1989 through June 1990. During these surveys we also sighted 15 chelonid sea turtles. We sighted 86 leatherback sea turtles from June 1988 through June 1990. Twenty-four were sighted in waters less than 200 m.

We concluded that for an area from the mouth of the Mississippi River, west to about 92°W longitude, the current Minerals Management Service/National Marine Fisheries Service mitigation measures should adequately protect sea turtles when explosives are used to assist petroleum platform removals. However, for the area offshore of the Breton and Chandeleur Islands including deeper waters of at least 60 m, special precautions should be taken. The probability will be high that one or more sea turtles may be near any given petroleum platform.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This study would not have been possible without the excellence and professionalism of the NOAA Aircraft Operations Center pilots that flew the Twin Otter aircraft: LT Brian Taggart, CDR Pat Wehling, CDR Dan Eilers, LT Tom Gates, LT Tim O'Mara, and LT Mike White. LT Taggart was pilot or copilot for nearly all surveys and his abilities and demeanor were outstanding. Susan Sutherland and ADM Speer were always helpful.

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INTRODUCTION

In 1988, there were 4,663 structures (platforms) in the Gulf of Mexico (Gulf) in use for petroleum production [United States Coast Guard (USCG)] (Figure 1). The U.S. Minerals Management Service (MMS) Gulf of Mexico Outer Continental Shelf Region had about 9.6 million hectares in the Gulf under 4,748 leases. About 1,600 of these leases were active. About 3,650 platforms under MMS jurisdiction had approximately 7,400 producing wells (Richardson 1989). Once a platform is no longer used for petroleum production, federal regulations require that the platform be removed.

In the process of removing a platform, explosives are often used to sever the pilings that anchor the platform to the bottom of the Gulf. Current restrictions limit the use of explosives as follows (Richardson 1989): (1) each explosive charge must weigh less than 22.7 kg; (2) detonations are limited to groups of 8 or less with a minimum of 900 milliseconds between detonations; (3) charges must be set at least 5 m (16 ft) below the "mud line;" and (4) high velocity explosives with a detonation rate of at least 7,600 m per second must be used.

The use of explosives has the potential to kill or injure marine animals, including sea turtles, in the vicinity of the platform. All five sea turtle species which occur in the Gulf are currently federally listed as either threatened or endangered under the provisions of the Endangered Species Act of 1973 (ESA) as amended (FWS 1989). Section 7 of the ESA requires federal agencies to confer when the actions of one agency may impact or jeopardize a threatened or endangered species. The National Marine Fisheries Service (NMFS) has jurisdiction over sea turtles in U.S. waters. The MMS oversees minerals development in U.S. waters. In compliance with the ESA the MMS consults with the NMFS prior to platform removal. The purpose of the consultation is to ensure that dangers to protected species during platform removal are minimized. Currently, for Gulf platform removals, a "generic" consultation is in effect that requires several mitigation measures (Richardson 1989):

1. an on-site observation program for at least the 48 h period prior to removal,

2. thirty-minute aerial surveys of the nearby area one hour prior and one hour after detonations,

3. no detonations if a sea turtle is observed within 915 m (1,000 yd) of the detonation site,

4. detonations can occur only from one hour after sunrise to one hour before sunset,

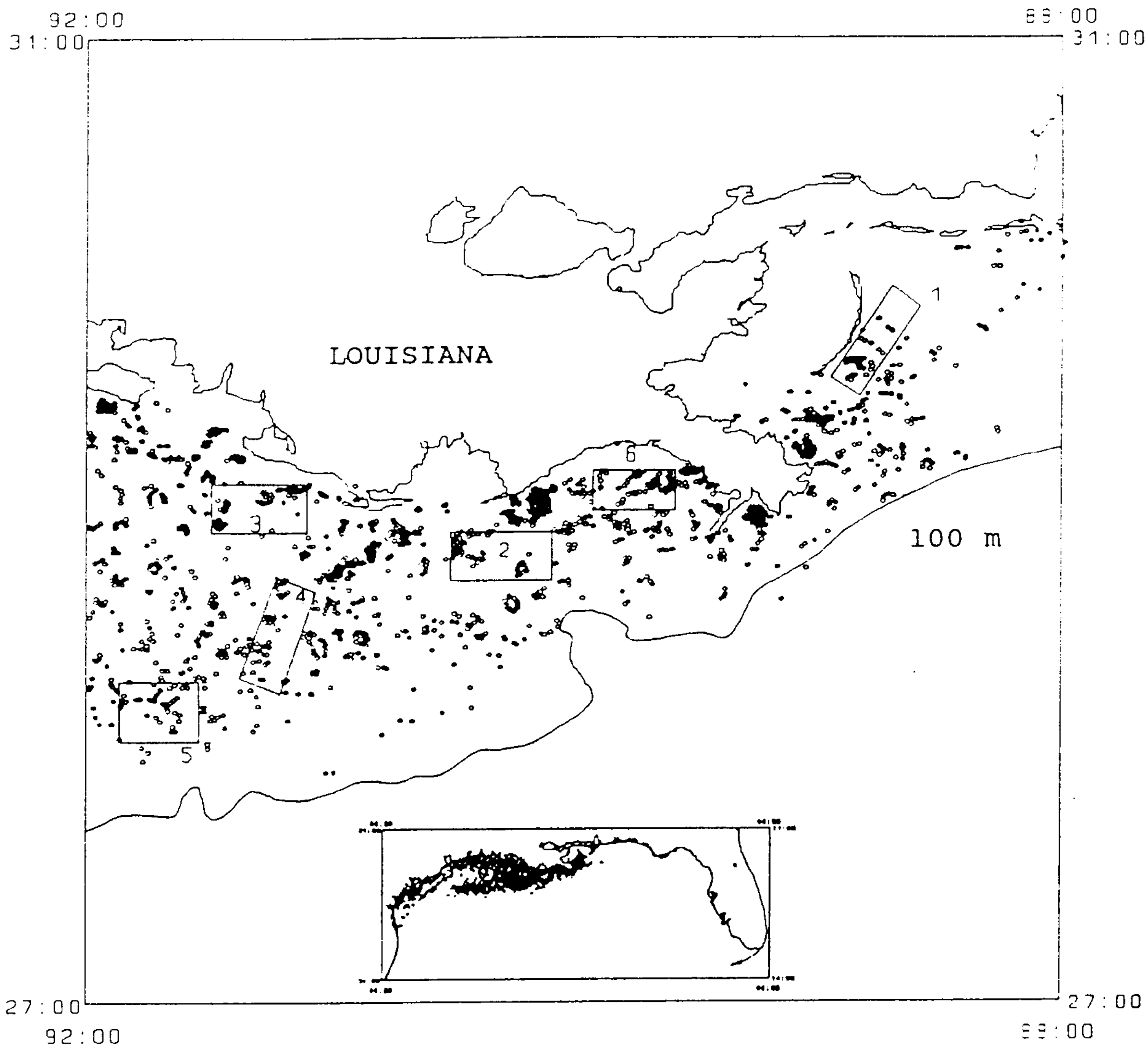


FIGURE 1. LOCATIONS OF AREAS 1-6 AND PETROLEUM PLATFORMS (o).

5. sea turtles observed by underwater workers must be reported, and

6. scare charges can only be used with prior approval.

The five species of sea turtles known to occur in the Gulf of Mexico are:

1. The loggerhead sea turtle (Caretta caretta), a threatened species, is currently believed to be the most abundant sea turtle in the Gulf of Mexico (Dodd 1988). The majority of loggerhead nesting in the United States occurs along the Florida and Georgia Atlantic coasts. Loggerheads nest much less frequently along the Gulf coast and greatest concentrations of nests seem to be in specific areas along the Florida coast and on the Chandeleur and Breton Islands, Louisiana (Carr et al. 1982).

2. The leatherback sea turtle (Dermochelys coriacea), the only non-chelonid sea turtle, is listed as an endangered species. Leatherbacks tend to be somewhat sporadic in occurrence and most abundant in water deeper than 100 m, however, leatherbacks can occur anywhere in the Gulf and have been observed in very shallow Gulf waters (Lohoefener et al. 1988). Leatherbacks nest sporadically throughout the Gulf and are rare. In July 1989, R. Watters (pers. comm.) reported a nesting leatherback on the Chandeleur Islands.

3. The green sea turtle (Chelonia mydas), when in the Gulf, is classified as a threatened species. (The Florida breeding population is listed as endangered.) At one time green sea turtles were probably common over sea grass beds throughout the Gulf, but heavy human predation drastically reduced their numbers (King 1982). Green sea turtles still occur in some numbers over grass beds along the southern Texas coast and along the Florida Gulf coast. Elsewhere, they are probably rare in occurrence.

4. The Kemp's ridley sea turtle (Lepidochelys kempi) is an extremely endangered sea turtle. The only significant nesting beach is located along the northern Gulf coast of Mexico. Less than 400 females were estimated to have nested in 1989. The shallow Gulf waters along the Louisiana coast are believed to be a major foraging area for both subadult and adult Kemp's ridleys (Liner 1954, Dobie et al. 1961, Viosca 1961, Carr et al. 1982).

5. The hawksbill sea turtle (Eretmochelys imbricata), an endangered species, is mainly a tropical and subtropical sea turtle. It is believed to be rare in the northern Gulf, but as many as 29 were found stranded on the Texas coast in 1986

(Amos 1989). Stranded hawksbills have also been reported from the Mississippi coast.

To date, observations, many anecdotal, suggest that sea turtles may be positively associated with petroleum platforms and, therefore, be endangered during the explosion (Hastings et al. 1975, Fuller and Tappan 1986, O'Hara and Wilcox 1987, Rosman et al. 1987, Klima et al. 1988). Skip Stevens (pers. comm.), a platform service boat captain, reported that large loggerheads were frequently observed at night near two of the 14 platforms he regularly visited offshore of the eastern Texas/western Louisiana coast. He also reported that sea turtles were usually only observed at night and they were not observed during the winter months. Some loggerheads may take up residence at specific platform structures. Loggerheads have been observed near specific platforms for periods of time (L. Ogren and I. Workman, pers comm.). Why loggerheads are found near specific platforms is not known.

While some sea turtles may be found near specific platforms, how the sea turtle population, in general, was distributed relative to petroleum platforms areas or specific platforms was unknown. Therefore, we conducted a study to investigate the spatial distribution of sea turtles relative to platform locations in the Gulf. This study applied only to relatively large sea turtles (carapace length generally greater than 70 cm) located near the surface of the water during daylight hours in the eastern portion of the petroleum platform field in the Gulf (from 88° to about 92° W longitude). Primarily, the study was designed to test two null hypotheses:

1. H_0: Surfaced sea turtles are randomly located with respect to platform locations, and

2. H_0: Surfaced sea turtle abundance in the northern Gulf of Mexico does not change with the seasons.

METHODS

Petroleum Platforms

Two petroleum platform data bases were used to design the study and for the data analyses: (1) the 1988 USCG data base, and (2) the 1988 MMS Gulf Region data base. Several of our study areas were in shallow waters near the Louisiana coast. Many platforms in Louisiana state waters were not in the MMS data base. The USCG data base referenced all platforms in both state and federal waters. In the past, the NMFS Mississippi Laboratories used the USCG data base to locate platforms for reef fish studies, so the USCG data base was known to be accurate. Therefore, the USCG data base was used as the source for platform locations.

However, except for the latitude and longitude of the platform, the USCG data base only contained information on the safety aspects of the platforms (lights, horns, etc.) and did not provide data characterizing each platform. The MMS data base contained this information and was cross referenced with the USCG data base. If the platform locations were similar (within 100 m), the platform locations were classified as describing the same platform. The MMS data was used to profile the platform. In an effort to learn why sea turtles may be attracted to specific platforms, platforms which were found to have more sea turtles than expected near them were compared to other platforms. The MMS data base included information on the following variables:

1. latitude and longitude (degrees, minutes, 0.01 minutes),
2. distance to shore (converted to kilometers),
3. water depth (converted to meters),
4. year of first production (age of platform),
5. number of decks (indicator of size),
6. number of slots (indicator of size),
7. number of slots drilled (indicator of underwater structure),
8. MMS ranking as major or minor structure (size indicator),
9. MMS record of manned or not (could be an important biological question),
10. number of beds (number of personnel, could have biological ramifications), and
11. type of production (natural gas, oil, water, and/or condensate - could have attraction or repulsion properties).

Study Areas

From June 1988 through September 1989, six areas were studied offshore of Louisiana (Figure 1). Each area was selected on the basis of two criteria: (1) the distribution of petroleum platforms and (2) water depths. The size of the study areas was determined by two criteria: (1) the number of platforms in and within 1 km of the study area, and (2) the time needed to survey the area.

The distribution of the petroleum platforms was important because one of the tests for association between sea turtles and platforms was a goodness-of-fit test. For this test, it was important that platforms were not uniformly or randomly distributed in the study areas. Study areas were configured so that each one had aggregations of platforms. The platforms in or within 1 km of each study area were profiled using variables in the MMS data base (Table 1).

Area 1 was just offshore of the Chandeleur Islands. Water depths ranged from about 6 to 25 m. The majority of the platforms were in the southern one-third of the study area. The four corners (latitude and longitude) of the study area were 29°58.0' 88°42.0', 29°53.0' 88°35.0', 29°30.5' 88°50.0', 29°35.0' 88°57.0'. This study area was chosen for three reasons: (1) it sampled the marine habitat east of the Mississippi River, (2) previous research (Lohoefener et al. 1988) had shown an abundance of sea turtles in the general area, and (3) loggerheads were known to nest on the Chandeleur Islands.

Area 2 was 11 km offshore of Timbalier Bay, Louisiana. Water depths ranged from less than 14 m to more than 38 m. This study area was chosen to sample these water depths west of the Mississippi River. The majority of the platforms were around the periphery in the western one-third of the study area. Opposite corners of the rectangular shaped study area were 28°57.0', 90°30.0' and 28°45.0', 90°05.0'.

Area 3 was 6 km offshore of Oyster Bayou, Louisiana. Water depths ranged from less than 3 m to slightly greater than 11 m. The majority of the platforms were in the northern and western portions of the study area. Opposite corners of the rectangular shaped study area were 28°57.0', 91°30.0' and 29°09.0', 91°06.0'. This study area was chosen to sample very shallow waters west of the Mississippi River.

Area 4 was in the Ship Shoals area 33 km offshore of the Louisiana coast. Water depths ranged from 13 to over 65 m. This study area was chosen for two reasons: (1) to sample the 30-65 m water depths west of the Mississippi River, and (2) we observed surfaced sea turtles in and near the northern part of this area during 1986 aerial surveys for red drum schools. The majority of the platforms were in the western one-half of the study area. The corners of the parallelogram shaped study area were 28°46.0' 91°14.0', 28°42.0' 91°04.0', 28°17.0' 91°13.0' and 28°21.0', 91°23.0'.

TABLE 1. PROFILE OF PLATFORMS IN EACH STUDY AREA.

Data Type	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Number of Platforms	59	78	155	64	40	106
Mean Distance to Shore (km)	42	20	24	71	125	14
Mean Water Depth (m)	13	20	7	35	75	16
Mean First Production Year	1975	1977	1967	1971	1977	1965
Mean Number of Decks	1.5	1.7	1.3	2.0	2.0	1.7
Mean Number of Slots	1.4	4.5	1.3	9.1	14.5	6.2
Mean Number of Slots Drilled	1.3	3.2	1.3	6.7	11.0	5.7
Percent Manned	16	27	14	43	62	26
Percent Major Platforms	35	36	25	84	96	61
Percent Producing Natural Gas	93	71	56	80	96	63
Percent Producing Oil	16	58	41	66	82	71
Percent Producing Water	7	32	17	56	78	24
Percent Producing Condensate	35	40	30	50	80	21

Area 5 was in the area of Eugene Banks 102 km offshore of the Louisiana coast. Water depths ranged from about 60 m to about 120 m. Platforms were widely scattered throughout the study area, but few platforms were along the eastern edge and the southwestern corner. Originally the study area was designed as a rectangle with transects that sloped from the northwest to the southeast. However, this orientation exacerbated the effects of glare on the water and, in August 1988, the orientation was changed to form a rectangle with east to west transects. Opposite corners of the study area were 28°20.0' 91°52.0' and 28°05.0', 91°33.0'. This study area was chosen to sample the deeper water depths west of the Mississippi River. Very few petroleum platforms are located in water deeper than 120 m.

Area 6 was 9 km offshore of Grande Isle, Louisiana. Water depths ranged from less than 11 m to slightly greater than 36 m. The majority of the platforms were in the northern one-half of the study area. Opposite corners of the rectangular shaped study area were 29°02.0' 89°35.0' and 29°12.0' 89°55.0'. This study area was chosen for three reasons: (1) because Viosca (1961) had reported that sea turtles used to nest on Grand Isle we wanted to determine whether a remnant population existed in the adjacent waters; (2) because currents associated with the west pass of the Mississippi River stratify the water's turbidity, this area is somewhat unique offshore of western Louisiana and; (3) surfaced sea turtles had been observed in this general area during surveys for red drum schools in 1986 and 1987.

After the first 16 months of surveys, it was apparent that there was a high density of sea turtles in the southern part of Area 1 which also had a large number of petroleum platforms. In order to define the region which had a high density of sea turtles in the platform area east of the Mississippi River, a new study area was surveyed which included the southern part of Area 1. This area was much larger and included much deeper water. This study area was designated Area T (Figure 2, also see Figure 8). The four corners of Area T were 29°42.0' 88°52.0', 29°22.0' 88°22.0', 29°01.0' 88°36.0' and 29°21.0' 89°06.0'. The water depths in this area ranged from 3 to over 200 m. Area T was surveyed during cold and warm weather periods to determine if sea turtles shifted their distribution to deeper water during the cold months.

Aerial surveys were also conducted in deep offshore waters of the north-central Gulf (Figure 2). The primary objective of these surveys was to study whales and dolphins. However, both chelonid and leatherback sea turtles were also sighted in these waters. The northern boundary of most of these study areas began at about the 200 m isobath. The study areas extended south for about 50 km. Maximum depths ranged from 730 m to over 2,000 m in Area A. Areas 7-9 and A were surveyed from July 1989 though November 1989. Deep water Blocks 1-7 were surveyed from January 1990 through June 1990.

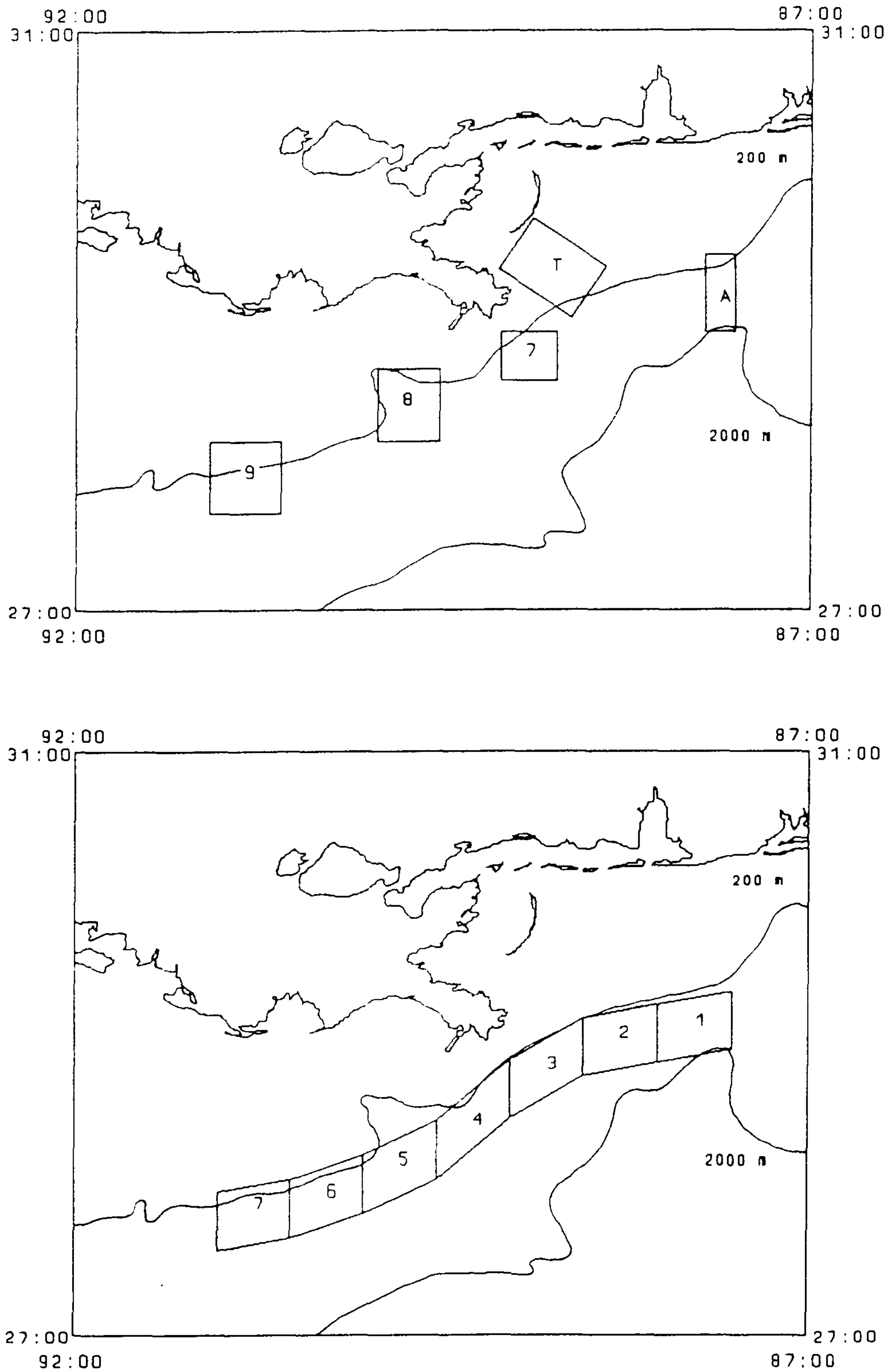


FIGURE 2. STUDY AREA T AND THE DEEP WATER STUDY AREAS AND BLOCKS (Areas, upper panel; Blocks, lower panel)

Study Periods

We surveyed Areas 1-5 from June 1988 through May 1989 (Table 2). Areas 1 and 6 were surveyed from July through September 1989. Because of the large number of sea turtles sighted in Area 1, we continued the surveys to better define the platform-sea turtle association. We surveyed Area 6 to confirm that a major population area of loggerheads was not overlooked. Except for December, Area T was surveyed from October 1989 through June 1990. The number of survey days ranged from 6-8 each month. However, during the first month of the study, June 1988, surveys were conducted on about twice as many days in order to refine the study methods.

Windy weather was the greatest hindrance to conducting successful surveys. Surveys were usually conducted from about 0900-1600 hours.

Study Platform

The study platform was a DeHavilland (DHC-6) Twin-Otter aircraft maintained and operated by the NOAA Aircraft Operation Center. The standard survey altitude was 229 m (750 ft). Rarely (<2%), low clouds required a survey altitude of 152 m (500 ft). In June 1988, the standard survey speed was 167 km/h (90 NM/hr). At that speed, most turtles sighted were diving and in July 1988, a ground speed of 185 km/h (100 NM/hr) was tried. We believed that many turtles were still reacting to the aircraft and in September 1988, and in all subsequent months, the survey speed was increased to a ground speed of 204 km/h (110 NM/hr). The change of survey speed may have resulted in fewer sea turtle sightings in June, July, and August than could have been sighted at the faster speed. Therefore, the estimates of sea turtle density could be more negatively biased in these months. Because the tests of association between sea turtles and platforms should not be affected by this negative bias, we ignored the change of aircraft speed in the data analyses.

Sampling Methods

Sampling Design

The study design was to survey Areas 1-5 four times each month (20 survey areas per month). We could survey three areas per daily flight. To use the flight time efficiently, one area, selected randomly each month, was studied five times. Area 6 was only surveyed three times each month because we were primarily investigating the presence or absence of sea turtles to determine whether additional studies in this area were needed. We assumed that if sea turtles used this area, they would have been present during the July through September study period.

TABLE 2. SURVEY EFFORT IN EACH SEA TURTLE STUDY AREA.

Month	Days surveyed	Area (effort in transect km)						
		1	2	3	4	5	6	T
1988								
June	14	733	810	977	969	1159	-	-
July	6	585	816	785	1,206	933	-	-
August	8	590	992	973	953	755	-	-
September	7	742	818	981	969	753	-	-
October	5	593	615	583	921	558	-	-
November	7	740	811	979	723	749	-	-
December	7	739	815	984	754	562	-	-
1989								
January	5	443	817	565	482	186	-	-
February	6	740	813	584	975	370	-	-
March	7	729	813	783	977	687	-	-
April	6	732	1013	780	726	652	-	-
May	7	592	810	758	973	754	-	-
June				no survey				
July	6	738	-	-	-	-	389	-
August	5	429	-	-	-	-	392	-
September	7	592	-	-	-	-	387	-
October	4	-	-	-	-	-	-	678
November	8	-	-	-	-	-	-	908
December				no survey				
1990								
January	6	-	-	-	-	-	-	536
February	2	-	-	-	-	-	-	271
March	6	-	-	-	-	-	-	813
April	6	-	-	-	-	-	-	680
May	6	-	-	-	-	-	-	679
June	8	-	-	-	-	-	-	949

To sample each study area, systematic transects from a single random starting location were used. Depending on the study area, the area was divided into 3, 5 or 6 equally-sized blocks. On each study day a random starting corner for each study area was selected. A random distance, to the nearest 0.01 minute, from that corner was then selected as the starting point for the first transect. Subsequent transects in the study area were the random distance from the edge of each block. Transect orientation for Areas 1, 4 and T was northeast-southwest and for Areas 2, 3, 5, and 6 it was east-west. Our goal each month was to survey about 50% of the surface area of each study area (assuming we could see a 2 km strip of water). Three transects were surveyed per study day in Areas 1 and 6, five in Areas 2-5, and six in Area 6. Area T was divided into two equal area east and west sections. The east and west sections were sampled on alternate days.

Data Collection

The Twin-Otter was equipped with large plexiglass bubble windows on each side of the aircraft. The bubble windows afforded two experienced observers with forward, lateral, rear, and downward visibility. Downward visibility was such that each observer could easily view an area on both sides of the transect line.

Observers, pilots, and the computer operator communicated by using headsets with voice activated microphones. A super high resolution video camera was mounted in the belly port of the aircraft. The camera continuously recorded the transect line and adjacent waters. This visual record was used to determine if observers missed sea turtles on or near the transect line. In addition to providing a visual record of each transect, all audio communications between observers were also recorded.

We identified five types of sea turtle sightings:

1. Confirmed Loggerhead Sea Turtle,
2. Confirmed Leatherback Sea Turtle,
3. Either a Green, Kemp's ridley, or Hawksbill Sea Turtle (identification and characteristics used to make the identification were noted in the log),
4. Chelonid Sea Turtle, Species Not Confirmed, but known not to be a loggerhead sea turtle, or
5. Unidentified Chelonid Sea Turtle.

Almost all Unidentified Chelonid Sea Turtle sightings were of sea turtles swimming underwater or diving far from the transect line.

In addition to sea turtles, we recorded data on cetaceans, fish, human activity, and pollution. Data records were used to describe the transects and a number of variables were used to describe the environmental conditions (water color, turbidity, etc.) (see Appendix 1).

In addition to sea turtle identifications, accurate estimates of sea turtle locations, relative to the transect line and the actual position, were critical to analysis of the data. When a sea turtle was sighted, we used an electronic Sperry AngleStar Digital Protractor to estimate the angle formed by the hypotenuse and adjacent side of the right triangle formed by the observer, the sea turtle and the point on the transect line when the turtle was perpendicular to the aircraft. A "peep sight" was attached to the sighting plane of the protractor. The sea turtle was centered in the peep sight, the hold button was pressed, and the sighting angle was recorded. This angle, along with the aircraft's latitude and longitude, altitude, and heading at the time of the sighting, were used to calculate the latitude and longitude of the sea turtle and its perpendicular distance from the transect line.

For other sightings, we divided each plexiglass bubble into seven intervals, 10° apart (0-10°, 11-20°, etc.) using the digital inclinometer and marked each interval on the bubble with a thin strip of tape. Perpendicular angles to other marine animals, human activities, and pollution were recorded as the median of the interval. We used this method because our primary goal was to observe as many sea turtles as possible and observers did not need to divert their eyes from the water to report the interval. Sightings outside of the last interval were not recorded.

A II Morrow LORAN-C navigation receiver was directly interfaced to a Toshiba 1100+ laptop computer. Output from the receiver was constantly stored in one of the computer's storage buffers. The LORAN receiver output cycled at about 0.015 to 0.02 minutes of latitude and/or longitude. When a LORAN latitude and longitude position was recorded in the data base, the last latitude and longitude in the buffer was used. Therefore, these latitudes and longitudes should be within about 0.02 minutes of the aircraft's actual location. At the latitudes of our study areas, 0.01 minute of latitude or longitude should be about 16 to 19 m of actual distance.

The LORAN receiver monitored the quality of the signals it was receiving from the three LORAN stations. Poor quality signals could lead to an erroneous latitude and longitude. If any of the signals were of poor quality, a flag was placed in the data recorded to indicate that the recorded position might not be accurate. However, no flagged sea turtle locations were ever recorded. [Three signal to noise ratios (SNRs) were used to monitor the reliability of the latitudes and longitudes. A poor quality signal occurred if the SNR was 64 or less.]

At the beginning of the study we tested the accuracy and precision of the reported LORAN locations by accessing the reported latitude and longitude of the aircraft as it flew over a specific point with a known latitude and longitude (the lighthouse on Chandeleur Island). The recorded position averaged within 200 m of the reported true location (se = 54.4).

Water surface temperatures were recorded by two methods. Initially, we used Precision Radiation Thermometers (PRT) to record the surface water temperatures at regular intervals along each transect and for each sighting. However, although we used three different PRTs and had each calibrated, reported temperatures varied greatly and did not agree with sea surface temperatures recorded by remote sensing from the NOAA-9 and NOAA-10 satellites. Therefore, sea surface temperature data were regularly down-loaded from these satellites.

In the warm months satellite data were acquired from night passes, when there was less haze in the air. Data were generally acquired from day passes during the cold months. Clouds often obscured some of the study areas and it was necessary to build a composite picture among days in a study month. The selected resolution was a surface temperature averaged over a 1.1 km^2 block. From each download, the surface temperature data for each study area were extracted and stored.

This method of acquiring surface temperatures was judged to be preferable to using PRTs. The complete download afforded a perspective of the "big picture" during the study month and among study months, and the 1.1 km^2 resolution was thought to be sufficient for questions concerning sea turtle habitat preferences.

Data Analyses

We pooled all chelonid sea turtle sightings for analytical purposes for two reasons: (1) all chelonid sea turtles in the Gulf are listed as threatened or endangered under the ESA and (2) only 7% of the chelonid sea turtles sighted were identified as either green or Kemp's ridley sea turtles. We assumed the same percentages of unidentified chelonids were loggerhead, and green or Kemp's ridley sea turtles. Unidentified chelonid sea turtles made up 21% of the sea turtles sighted overall. Pooling the data allowed us to increase the sample size for the analyses. Because leatherbacks have such a different appearance, and because the life history of leatherbacks seems to differ so greatly from chelonid sea turtles, we treated leatherbacks separately. (Unless stated otherwise, we use "sea turtle" throughout the remainder of the text to indicate a chelonid sea turtle sighted at or near the surface of the water during daylight hours.)

When testing hypotheses, we used an alpha (α) of 0.10 as a level of significance. Because all sea turtles are listed as threatened or endangered, and since the erroneous acceptance of the null hypotheses might tend to jeopardize sea turtles, we elevated the α (from the usual 0.05) to reduce the risk of incorrectly accepting a null hypothesis.

Density Estimation

We used line transect methods to estimate the density of sea turtles. Burnham et al. (1980) recommended that sighting functions should be based on a minimum of 40 sightings, but stated 60-80 sightings were preferable. Because a sufficient number of sea turtles were sighted only in Area 1, we pooled all sea turtle sightings to form a sighting function. To estimate $\hat{f}(0)$, the value of the probability density function evaluated at the transect line, the perpendicular distances were grouped into 100 m intervals and truncated at 600 m to form an overall sea turtle sighting histogram. A hazard-rate model (Buckland 1985) was fit to the histogram. We selected the hazard-rate model for two reasons: (1) the number of parameters in the model is fixed (there was no subjective decision regarding the number of parameters), and (2) the model always has a shoulder near the transect line (distance zero). However, we also examined the other available models to compare them with the hazard-rate. The half-normal and the Fourier series models were assessed with program TRANSECT (Laake et al. 1979). The hazard-rate and Hermite polynomial models were assessed with programs HAZARD and HERMITE (Buckland 1988). The Fourier series and Hermite polynomial models can have variable number of parameters. We evaluated the goodness-of-fit between the observed sighting histogram and the expected distribution generated from each model using a chi-square (X^2) goodness-of-fit test.

Based on the comparison of models, we retained our initial choice of the hazard-rate even though it's overall fit to the observed data was not as good as the other models (Table 3, Figure 3). The Fourier series did not fit the observed data well at the transect line, the area most critical to estimation of $\hat{f}(0)$. The Hermite polynomials with three and four terms were spiked near the transect line (did not have smooth shoulder). The other models, which had better fits, also generated the same estimate of f(0) as the hazard-rate (0.0036).

The density of sea turtles per month ($\hat{D}$, sea turtles/km^2) for each study area was estimated using survey days (i) as replicates as

$$\hat{D}_i = \frac{n_i \ \hat{f}(0)}{2 \ \ell_i}, \qquad \hat{D} = \frac{\Sigma \ell_i \hat{D}_i}{\Sigma \ell_i}$$

TABLE 3. SIGHTING MODELS USED TO ESTIMATE $\hat{f}(0)$.

Model	$\hat{f}(0)$	$se_{(\hat{f}(0))}$	n	X^2	df	P
Hazard	0.00355	0.00029	2	10.60	3	$P < 0.025$
Fourier	0.00331	0.00006	1	6.92	4	$P = 0.14$
Half-Normal	0.00360	0.00018	1	6.01	4	$P = 0.20$
Hermite	0.00360	0.00018	0	6.04	4	$P > 0.25$
Hermite	0.00356	0.00027	1	5.99	4	$P > 0.25$
Hermite	0.00362	0.00027	2	5.22	3	$P > 0.10$
Hermite	0.00403	0.00035	3	1.57	2	$P > 0.25$
Hermite	0.00403	0.00042	4	1.57	1	$P > 0.10$

n - number of parameters; X^2 - chi-square; df - degrees of freedom

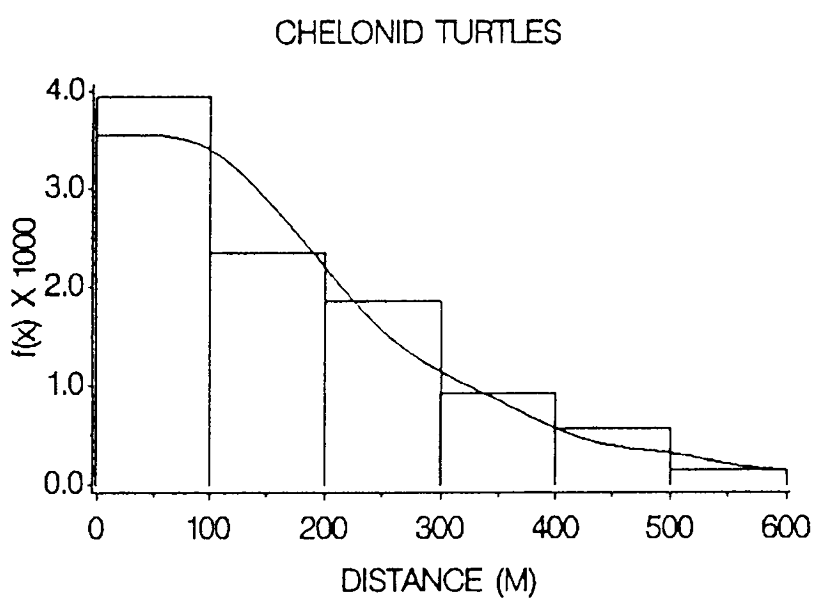


FIGURE 3. HAZARD-RATE MODEL FIT TO THE SEA TURTLE SIGHTING DISTANCE DATA.

where n was the number of sea turtles and ℓ was the total transect length per survey day per study area. (Too few leatherbacks were sighted to estimate density.) We used an empirical estimator (Burnham et al. 1980) to estimate the variance of $\hat{D}$,

$$\hat{var}(\hat{D}) = \frac{\Sigma \ell_i (\hat{D}_i - \hat{D})}{\Sigma \ell_i \ (R - 1)}$$

where R was the number of survey days per study area each month.

Sea turtle density was estimated for three seasons. The seasons were as follows: April through July, "spring"; August through November, "fall"; and December through March, "winter." The spring months are when loggerhead sea turtles generally aggregate and nest. The winter includes the months when some type of movement, migration or brumation may be expected of sea turtles in response to cooler water temperatures. [As suggested by Dodd (1988), we use the term brumation instead of hibernation because it does not imply the same physiological changes associated with hibernation by warm-blooded animals.] Using only three seasons also helped maintain larger sample sizes for the analyses.

Sea Turtle Associations with Platforms

We tested the null hypothesis,

H_0: Sea turtles were randomly located with respect to platform locations,

using three analytical methods: (1) Hamill and Wright's (1986) method, (2) Kendall's measure of rank correlation, and (3) chi-square goodness-of-fit. We used three methods because, for analyzing spatial data, Upton and Fingleton (1985) stressed the importance of not always drawing conclusions from only one type of test. This is partially due to the fact that many times subjective decisions made by the investigator can influence the outcome of the test. For example, in chi-square analyses (see below), the spatial area under consideration can be divided into few or many cells. For correlation analyses the number of random points tested is largely up to the discretion of the investigator. Because the Hamill and Wright test is suited exactly for the problem at hand, the relationship of one set of points to a fixed set of points, it is the best and most powerful test of the three and is not plagued by subjectivity. However, to our knowledge we are the first to use it on field data, therefore its use merits caution and comparison to more classical tests to verify its veracity.

Hamill & Wright's Method

Hamill and Wright's (1986) method investigates the relationship between the locations of two sets of points. Initially, this test was developed to analyze the dispersion of juvenile plants relative to conspecific adults. The method tested whether juvenile plant locations were positively, negatively or randomly associated with adult plant locations. This method, however, can be used to the describe a relationship in any situation where two types of points can be recognized. In this study, we were interested in whether sea turtles were positively associated (generally closer to), negatively associated (generally more distant from) or randomly associated ("indifferent" to) with petroleum platforms. We used Hamill and Wight's method to test the dispersion of sea turtles ("juveniles") relative to platforms ("adults").

The analyses required that the sea turtles were in a bounded plane (i.e., a study area). However, platforms inside of and outside of each study area were needed for each analysis (because the nearest platform to a sea turtle was not always in the study area). Therefore, we extracted the locations of all platforms inside of and within 1 km of each study area from the USCG data base. Using the two sets of locations, two cumulative probability distributions were generated for each analysis: (1) the distribution expected if sea turtles were located randomly with respect to platforms, and (2) the observed distribution of sea turtle locations with respect to platforms. The expected probability distribution was generated by estimating the proportion of the total study area which was within a given radius of any platform. The radius was increased in increments of 100 m until all of the area was accounted for in the study area. The observed probability distribution was generated by dividing the cumulative number of sea turtles located within each radius increment by the total number of sea turtles in the study area. Under the null hypothesis, if sea turtles were dispersed randomly with respect to platforms, the percent area within a given radius of the platforms should also be the same as the percentage of sea turtles within that radius.

The two cumulative probability distributions were plotted on the same graph. If the observed distribution was "above" the expected distribution, then sea turtles might be closer than expected to the platform locations (positive association). (See for example, Figure 5, both distributions in each case must eventually sum to one but the observed distributions approached one at a faster rate.) If the observed distribution was "below" the null distribution then sea turtles might be more distant than expected from the platform locations (negative association). If both distributions were the same, then the null hypothesis would be accepted. To determine whether the observed distribution was significantly different from the expected, the distance between the two distributions was tested with the Kolmogorov-Smirnov (KS) test (Conover 1971). The KS test was performed at 100 m intervals to determine over what distance range the relationship was significant. If a relationship is significant, since both distributions must sum to one, the significance will always be lost at some distance.

We used Hamill and Wright's (1986) program FASTNAD to model the observed and expected cumulative probability distributions and to perform the KS tests. We checked the accuracy of the program by using a computer to generate ten simulations where "sea turtle" data sets produced had distributions which were specified as positively, negatively or randomly associated with platform locations. Secondly, simple platform and sea turtle data sets were plotted and expected and observed distance distributions were measured. In both tests, the results from Hamill and Wright's test agreed with the generated data set probabilities.

We also tested sea turtle locations for association with "hangs." A hang is an underwater obstruction (e.g., sunken vessel), usually reported by trawl fishing and research vessels. Since a "hang" may provide underwater structure similar to a platform, the spatial relationship between "hangs" and sea turtles may be similar to that of platforms and sea turtles. We used the locations of reported hangs in the NMFS "hang" data base. The data base consisted of the latitude and longitude of the hang, the type of hang (rarely known) and the source of each known hang. "Hang" locations inside of and within 1 km of each study area were used as the "adult" data base in each Hamill and Wright analysis.

Kendall's Measure of Rank Correlation

Another method used to test whether sea turtle and platform locations were associated was a test of positive or negative correlation (Upton and Fingleton 1985). This was done by generating random points within each study area and calculating the distances from each random point to the nearest platform location (x_{1i}) and the nearest sea turtle location (x_{2i}). If the sea turtle locations and platform locations were independent of each another, there should not be a significant correlation between X_1 and X_2. If sea turtles were positively associated with platforms, then the x_{1i} and x_{2i} distances should be positively correlated. If sea turtles were negatively associated with platform locations, the distances should be negative correlated.

One problem with this type of test is specifying what constitutes significant correlation. Any number of random points could be generated. If too few points were generated, the test would lack power. As the sample size of random points increases, the level of correlation required to attain statistical significance decreases, and correlations may become statistically significant, but lack practical significance.

We arbitrarily selected 100 randomly generated points per test. For each sea turtle/platform data set, we repeated Kendall's test ten times using ten different sets of points. We used SAS statistical software to generate Kendall's coefficient of rank correlation and the associated probability level for each test. For each data set, the ten probability levels were compared. If six or more of the ten Kendall's test values were significant ($P \leq 0.10$), then we considered sea turtle and platform locations to be correlated. If the correlation coefficients were positive, we concluded sea turtles were positively associated with platform locations. If the coefficients were negative, the conclusion was that sea turtles were negatively associated with platforms.

Chi-square Goodness-of-fit Tests

The third method used to test for association between sea turtle and platform locations was chi-square goodness-of-fit tests. The study areas were purposely selected so that the majority of platforms in each area were aggregated in one part of the area. Depending on how the platforms were aggregated, we partitioned each study area into four equal area "east-west" (Areas 2, 3, 4 and T) or "north-south" (Areas 1 and 3) cells. Area 3 was tested in both directions because platforms were concentrated to the northeast and southwest. For each sea turtle/platform data set, we divided the total number of sea turtles and the total number of platforms by four to generate the expected number of sea turtle and platforms in each cell. This was the number of sea turtles or platforms expected if sea turtles and platforms were randomly located in each study area. The observed distribution in each case was the actual number of sea turtles or platforms in each cell. We used a chi-square goodness-of-fit test (Conover 1971) to compare the observed and expected distributions for each data set for both sea turtles and platforms.

By design, the chi-square value for platform locations was highly significant. If the results of the goodness-of-fit tests for sea turtles indicated that they were not randomly distributed in the study area, the cells were examined to determine which cell had more sea turtles than expected and which had fewer. If the cells with more sea turtles than expected were also the cells with the most platforms, then sea turtles were considered positively associated with platforms. If the cells with more sea turtles than expected were cells with fewer platforms than expected, then sea turtles were considered to be negatively associated with platforms. If the distribution of sea turtles was not significantly different than expected, then the null hypothesis that sea turtles were randomly located with respect to platform locations was considered correct.

Sea Turtle Locations and Water Depths

The study areas were chosen to sample the range of water depths where platforms are found offshore of Louisiana. Water depths also varied within each study area. We used NOAA bathymetric charts and estimated the percentage of surface area within selected water depth strata for each area. We then used these percentages to estimate the number of sea turtles (from the total number sighted) that would be expected to occur within each water depth strata if sea turtles were randomly distributed in the study area. We compared this distribution to the number of sea turtles actually observed in each stratum. We used the chi-square goodness-of-fit test to test the null hypothesis that sea turtles were distributed in direct proportion to the areas of available water depth strata.

Sea Turtle Locations and Sediment Types

To a lesser extent, the study areas were also selected to sample different sediment types. We used the NMFS sediment type data base (Benton and Thompson 1988). We divided the sediments into four dominant types: sands, clays, silts, and no dominance (sands/clays/silts). We estimated the surface area within each study area that had each these types of sediments. We used these percentages to estimate the number of sea turtles that would be expected to occur, if sea turtles were randomly distributed in the study area over these sediment types. We used the chi-square goodness-of-fit test to compare the observed distribution of sea turtles to the expected and to test the null hypothesis that sea turtle were distributed in direct proportion to the area of available sediment types.

Sea Turtle-Platform Distance Probabilities

If any platform selected at random off the Louisiana coast were slated for removal with the aid of explosives, what is the chance that a sea turtle will be within 1,000 m of the platform (current mitigation measures) and therefore potentially harmed? To estimate this probability, we divided the petroleum field offshore of Louisiana into five "Habitat Zones" primarily based on water depth strata (Table 4). We estimated the surface area in each Habitat Zone. We assumed that the sea turtle density and sea turtle-platform association (random, positive or negative) results in each of our five study areas applied to the entire Habitat Zone that each respective study area represented (see Table 4). We estimated the probability that a sea turtle was within each of four distance intervals (0-500, 0-1,000, 0-1,500 and 0-2,000 m) of any

TABLE 4. DESCRIPTION OF THE FIVE HABITAT ZONES.

Habitat Zone	Area km^2	Description	Number of Platforms
Zone 1	2,178	Based on results from Area 1, from 30° N latitude to the mouth of the Mississippi River, water from the barrier islands out to the 13 fm isobath.	268
Zone 2	8,475	Based on results from Area 2, from the mouth of the Mississippi River to 92° W longitude, water from the 7 to the 20 fm isobath.	892
Zone 3	6,750	Based on results from Area 3, mouth of the Mississippi River to 92° W longitude, water from the mainland to the 6 fm isobath.	1,320
Zone 4	14,365	Based on results from Area 4, from the mouth of the Mississippi River to 92° W longitude, water from the 7 to the 34 fm isobath.	1,094
Zone 5	4,459	Based on results from Area 5, from the mouth of the Mississippi River to 92° W longitude, water from the 34 to the 53 fm isobath.	113

randomly selected petroleum platform for each Habitat Zone using four types of information:

1. The number of platforms in the Habitat Zone - We used the USCG data base to estimate the number of platforms in each Habitat Zone.

2. The percent of all surfaced sea turtles within 500, 1,000, 1,500, and 2,000 m of the nearest platforms - Because sea turtles were significantly associated with platform locations in Area 1, for Habitat Zone 1, to estimate the percentage of sea turtles within each distance interval, we used the observed percent of sea turtles in each interval. For the other four Habitat Zones, because the observed sea turtle to platform distances did not differ significantly from the expected, we sampled each Habitat Zone 10-12 times for locations of platforms in specified areas. We then used Hamill and Wright's method to compute the expected proportion of the area within each of the four distance intervals to platforms. We then averaged the 10-12 percentages from each Habitat Zone for the expected percentage.

3. The estimated abundance of surfaced sea turtles in a Habitat Zone - For each Habitat Zone we used the estimated density of sea turtles observed in the respective study area. For Habitat Zone 1 we used seasonal density estimates. For the other four areas, because of small number of sea turtles sighted, we used the overall estimate from the entire study.

4. The estimated percentage of time a sea turtle spends at the surface - No reliable estimates for the percentage of time a sea turtle spends at the surface of the water exists. Most studies have been conducted on loggerheads. Since we assumed most (93%) of our sea turtle sightings were loggerheads, a correction factor based on loggerheads is probably valid. In all published studies to date, the sample sizes have been small and no study has tested whether the telemetric transmitters and their method of attachment affected sea turtle surfacing behavior. Published estimates of surface time for large loggerheads ranged from 1% (Keinath 1986) to 75% (Kajihara et al. 1983). There are probably many factors, such as water temperature, breeding season, turtle size, etc., that determine how long a loggerhead spends at the surface. In 1981, NMFS Mississippi Laboratories, attached radio transmitters on 20 large loggerheads offshore of Cape Canaveral, Florida (Kemmerer et al. 1983). Some of these turtles were monitored for 20 days. The experiment was repeated in 1982 with 19 large loggerheads and a 35 day study period (Nelson et al. 1987). Results from the 1981 study, when water temperatures were somewhat warmer, suggested that

loggerheads were spending about 4% of their time at the surface. The water was cooler in 1982 and they spent an average of about 8% of their time at the surface. However, in both of the experiments, most of the data was from only a few loggerheads.

We used 12.5 as a calibration factor (the reciprocal of 8%) to estimate "absolute" density of all chelonid sea turtles from the estimated density of sea turtles at the surface for three reasons: (1) the 1982 study had one of the larger sample sizes, (2) the study was conducted in water depths similar to depths in our study areas, and (3) the loggerheads were similar in size to the loggerheads we observed.

To determine the sea turtle-platform distance probabilities, the "absolute" number of all sea turtles in each Habitat Zone was estimated by multiplying the estimated density of sea turtles at the surface by the 12.5 correction factor and extrapolating to the total area within the Habitat Zone. In Habitat Zone 1, the absolute number of all sea turtles was then multiplied by the estimated percentage of all sea turtles within 500, 1,000, 1,500, and 2,000 m of the nearest platform. In the other four Habitat Zones, the estimated number of all sea turtles was multiplied by the estimated percentage of the total area within 500, 1000, 1500 and 2000 m of the nearest platform. The total number of sea turtles within each distance interval was then divided by the known number of platforms in the Habitat Zone. For each distance interval, this quotient was the mean probability that a sea turtle was within that distance interval of any randomly selected platform in the Habitat Zone.

We assumed sea turtles were not agonistic, that is, the probability of one sea turtle being near a platform did not influence the probability of another sea turtle being within some distance of the same platform. Therefore, once the mean probability (μ) for each distance interval was estimated, the probability that none, one, two, three sea turtles, etc., were within each distance interval could be estimated using the Poisson distribution (Sokal and Rohlf 1981),

$$f(x) = \frac{e^{-\mu}\mu^{x}}{x!}$$

where e was the base of natural logarithms and x was 0, 1, 2, 3, etc. If for any specific platform, f(x) was less than 0.10 for any distance interval, then that platform was labeled "nearest" platform to one or more sea turtles. In other words, "nearest" platforms had more sea turtles sighted near them than would be expected by chance alone. We compared all "nearest" platforms to all the "other" platforms ($P > 0.10$) in the Habitat Zone using the variables in Table 1. This was done to determine if platforms with one or more, perhaps resident, sea turtles had similar unique characteristics compared to "other" platforms.

RESULTS

Sea Turtle Sightings

During the course of the study, in Areas 1-6 and T, 318 sea turtles were sighted and were identified as follows: 229 loggerheads (72%), 68 unidentified chelonids (21%), and 21 greens or Kemp's ridleys (7%). (Leatherbacks are treated below.) During the June 1988-May 1989 study period, most of the sea turtles (68%) were sighted in Area 1 and only about 2% were sighted in Area 5 (Table 5). No sea turtles were sighted in Area 6. All sightings of sea turtles by study areas for each month are included in Appendix 2.

In the deep water (>200 m) Areas and Blocks (Figure 2), 15 sea turtles were sighted from July 1989 through June 1990 (see Figure 15). A sea turtle was sighted in each deep water area except Area 8, Area 9, and Block 7. Of the 15, four sea turtles were sighted in January (0.25/100 km surveyed) and five in June (0.16/100 km).

Sea Turtle Abundance

Sea turtles were by far most abundant in Areas 1 and T (Table 6). Sea turtles were observed during every study month in Area 1. Sea turtles were sighted in every month surveyed in Area T except February 1990. However, due to poor weather in February, only two surveys were conducted. The abundance of sea turtles in Areas 1 and T was greatly reduced during the winter months. However, the relative abundance of sea turtles (measured as sighting rate) in Areas 4 and 5 appeared to increase from fall to winter (Table 7).

Sea Turtle Associations with Platforms

Hamill and Wright Analyses

Sea turtles in Area 1, except during winter, were more commonly sighted in the southern portion of the study area where the majority of the platforms were concentrated (Figure 4). In winter the most sea turtles were sighted in the central portion of the study area. The Hamill and Wright analyses indicated that sea turtles were, except during the winter months, positively associated with platform locations in Area 1 at distances ranging from 800-12,400 m ($P \leq 0.10$, Table 8). More sea turtles were at the distances from platforms over the range of significance than would be expected under the random hypothesis. This relationship is graphically illustrated by plotting the observed and expected cumulative probability distributions. The observed distribution approaches one at a significantly faster rate than the expected (Figure 5). For example, for all the sea turtles sighted in Area 1, 50% were within 2,000 m of a platform whereas only 31% of the

TABLE 5. SEA TURTLES SIGHTED IN EACH STUDY AREA.

Area	Study Period	Chelonids n	Chelonids %
1	Jun 88-May 89	150	68
2	Jun 88-May 89	26	12
3	Jun 88-May 89	15	7
4	Jun 88-May 89	23	11
5	Jun 88-May 89	5	2
6	Jul 89-Sep 89	0	
1	Jul 89-Sep 89	44	
T	Oct 89-Jun 90	55	

n - total number of turtles sighted

TABLE 6. DENSITY OF SEA TURTLES (sea turtles/100 km^2) IN EACH STUDY AREA.

Area	$\hat{D}$	$se_{\hat{D}}$	Study Period
1	3.25	1.00	Jun 88 - Sep 89
1	4.83	1.30	"Spring"
1	3.32	1.23	"Fall"
1	1.14	3.14	"Winter"
2	0.50	0.25	Jun 88 - May 89
3	0.22	0.20	Jun 88 - May 89
4	0.39	0.25	Jun 88 - May 89
5	0.11	0.09	Jun 88 - May 89
6	0	-	Jul 89 - Sep 89
T	1.90	0.30	Oct 89 - Jun 90
T	2.57	0.58	"Fall"
T	0.92	0.36	"Winter"
T	2.00	0.43	"Spring"

$\hat{D}$ - overall weighed estimate of density in sea turtles/100 km^2

TABLE 7. SEA TURTLE SIGHTING RATES (sea turtles/100 km) FOR JUNE 1988-MAY 1989.

	"Spring"			"Fall"			"Winter"		
Area	L	n	R	L	n	R	L	n	R
1	2,642	84	3.17	2,665	48	1.80	2,651	22	0.83
2	3,449	11	0.32	3,236	13	0.40	3,258	2	0.06
3	3,300	9	0.27	3,516	5	0.14	2,916	1	0.03
4	3,874	12	0.31	3,566	2	0.06	3,188	9	0.28
5	3,498	3	0.09	2,815	0	0	1,805	2	0.11
T	2,309	25	1.08	1,586	23	1.45	1,349	7	0.52

L - transect length in km; n - sea turtles sighted
R - sighting rate in sea turtles/100 km

TABLE 8. SEA TURTLE ASSOCIATIONS WITH PLATFORMS IN AREAS 1 AND T.

		Range of Significance* (meters)	
Area Survey Period	n	Minimum	Maximum
Area 1			
Jun 88-Sep 89	190	800	12,400
Jun 88-May 89	152	900	11,100
Jul 88-Sep 88	44	900	5,600
Jul 89-Sep 89	38	900	7,200
"Spring"	82	2,700	8,300
"Fall"	48	900	8,300
"Winter"	22	ns	ns
"Southern 1/3"	116	900	1,300
Area T	55	1,800	2,100

n - sea turtles sighted; ns - nonsignificant
* - determined by Hamill and Wright analysis

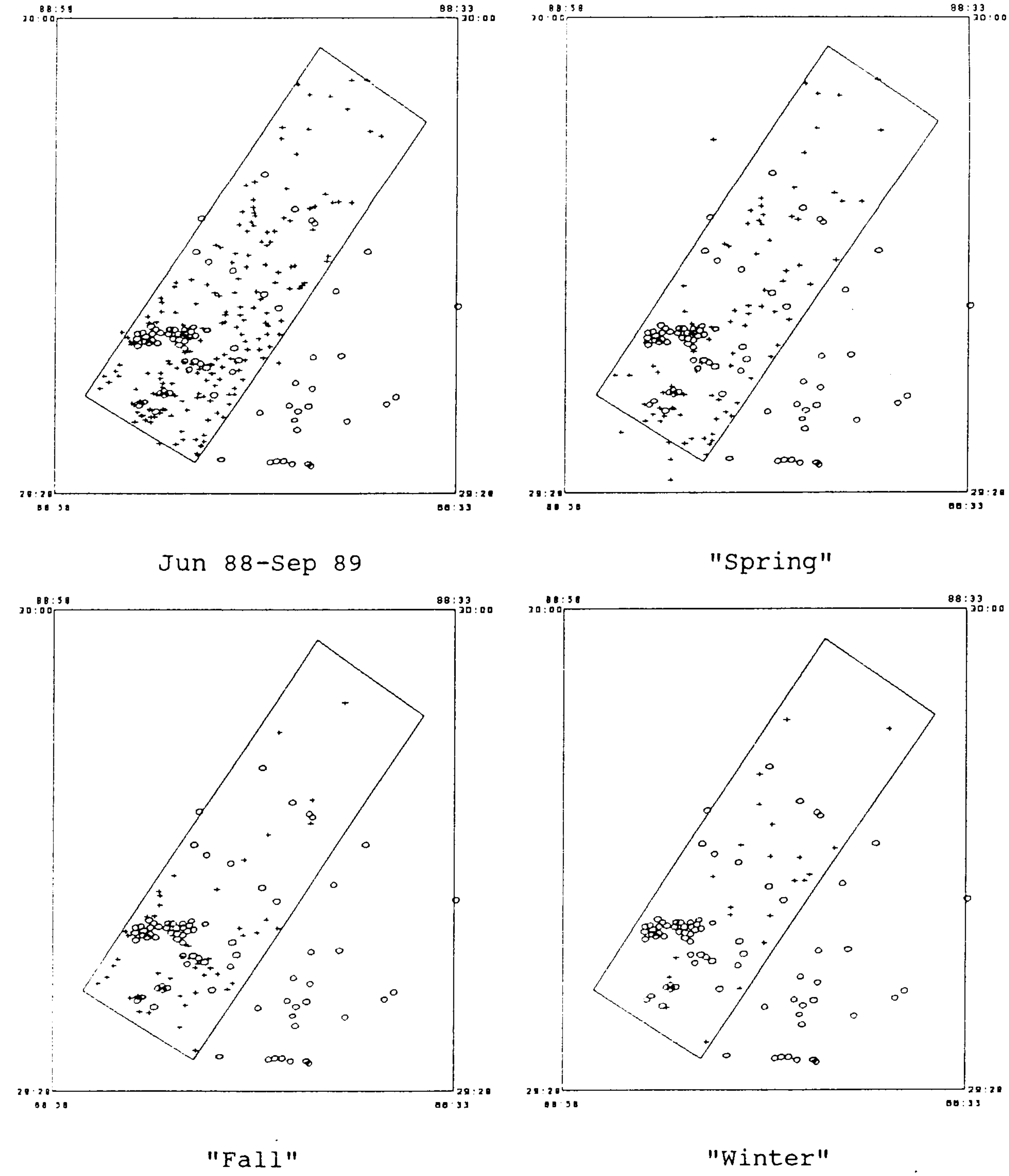


FIGURE 4. LOCATIONS OF PLATFORMS (o) AND SEA TURTLES (+) IN AREA 1.

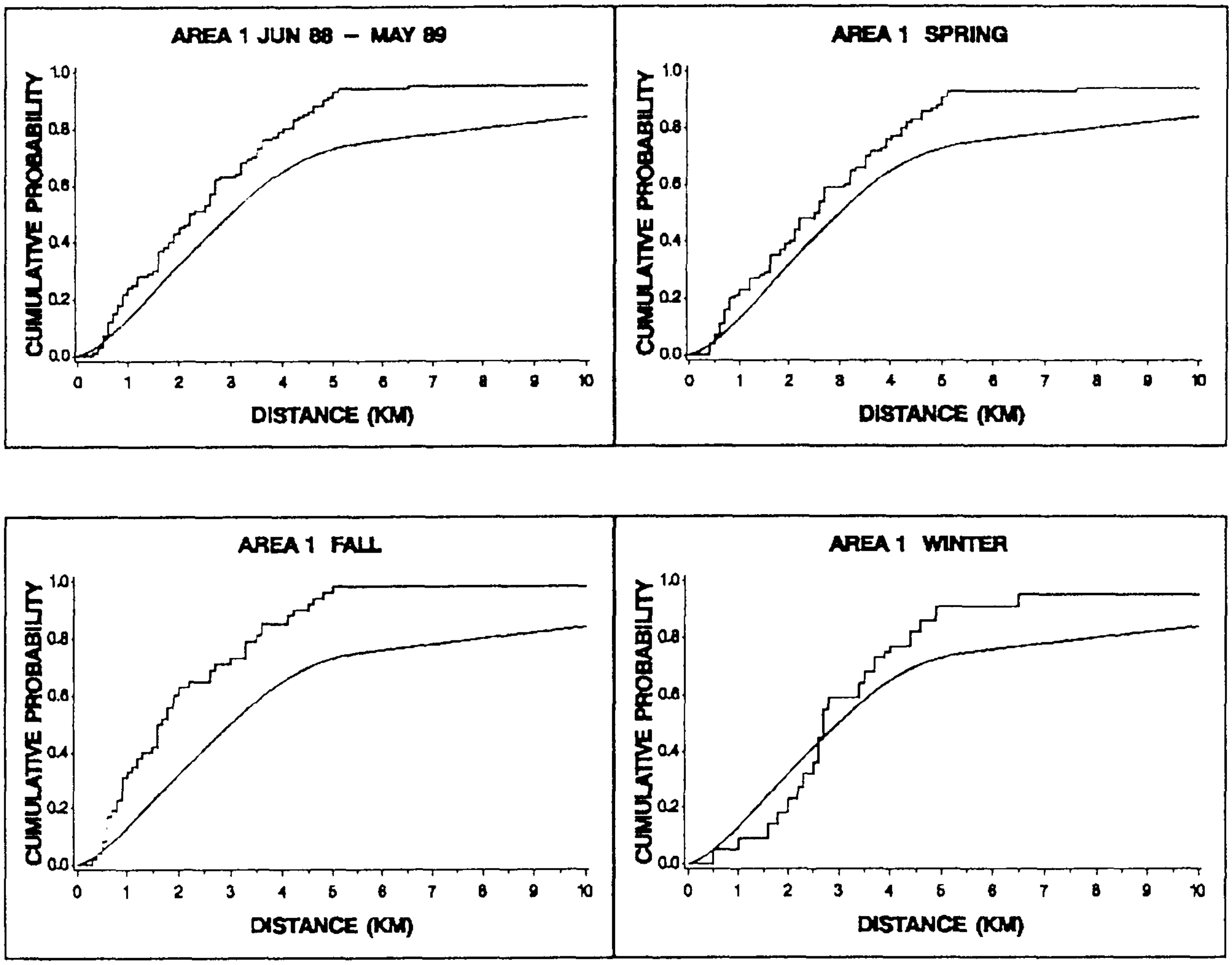


FIGURE 5. HAMILL AND WRIGHT ANALYSES FOR AREA 1 (observed distribution = step function, expected = continuous).

sea turtles were expected to be within that distance (i.e., 31% of the total area of Area 1 was within 2,000 m of a platform).

The seasonal analyses indicated that the fall distribution of sea turtles had a major influence on the overall results. In the fall, most sea turtles were in the southern one-third of the area. In the spring, the distribution was less concentrated. Sea turtles, at least the females, were probably spreading out all along the islands to nest and this dispersal may have attenuated the southern concentration of turtles. In the winter, sea turtles appeared to be randomly distributed with respect to platforms.

Analysis of the distribution of platforms and all sea turtles sighted in the southern one-third of Area 1 did not change the minimum distance at which significance was attained, but did, as expected, reduce the maximum distance. This was partially because the area was smaller. (In the southern one-third, the maximum distance a sea turtle could be from a platform was 5,500 m; for all of Area 1 the distance was 22,000 m.) In the southern one-third, the sea turtles were positively associated with platforms at distances from 900 to 1,200 m ($P \leq 0.10$). Forty-seven percent of the sea turtles were sighted within 1,200 of a platform; only 33% were expected. Fifty-three percent of the sea turtles were sighted at distances greater than 1,200 m from any platform, and were generally distributed at random with respect to platforms. The analysis for all of Area 1 would indicate that sea turtles were drawn into the area where there were platforms. The analysis for the southern one-third indicates that once in the area, some sea turtles were positively associated with platforms and/or sea turtles spend part of their time positively associated with platforms.

There were no apparent concentrations of sea turtles in Areas 2-4 (Figure 6). The Hamill and Wright analyses indicated sea turtles were randomly located with respect to the platform locations in these areas (not positively or negatively associated, $P > 0.10$). The observed cumulative probability distribution in Area 2 was very close to the expected random distribution (Figure 7). The observed distribution of sea turtles in Area 3 indicated sea turtles were somewhat negatively associated with platforms. In Area 4, the observed distribution indicated sea turtles were somewhat positively associated with platforms. However, neither relationship was significant. Too few sea turtles were sighted in Areas 5 and 6 for meaningful association analysis.

Sea turtles were more commonly sighted in the northwestern portion of Area T. (This was the southern one-third of Area 1.) Platforms in Area T were concentrated throughout the entire western third of the study area (Figure 8). The Hamill and Wright analysis indicated that sea turtles in Area T, were positively associated with platform locations from 1,800 to 2,100 m ($P \leq 0.10$, Table 8

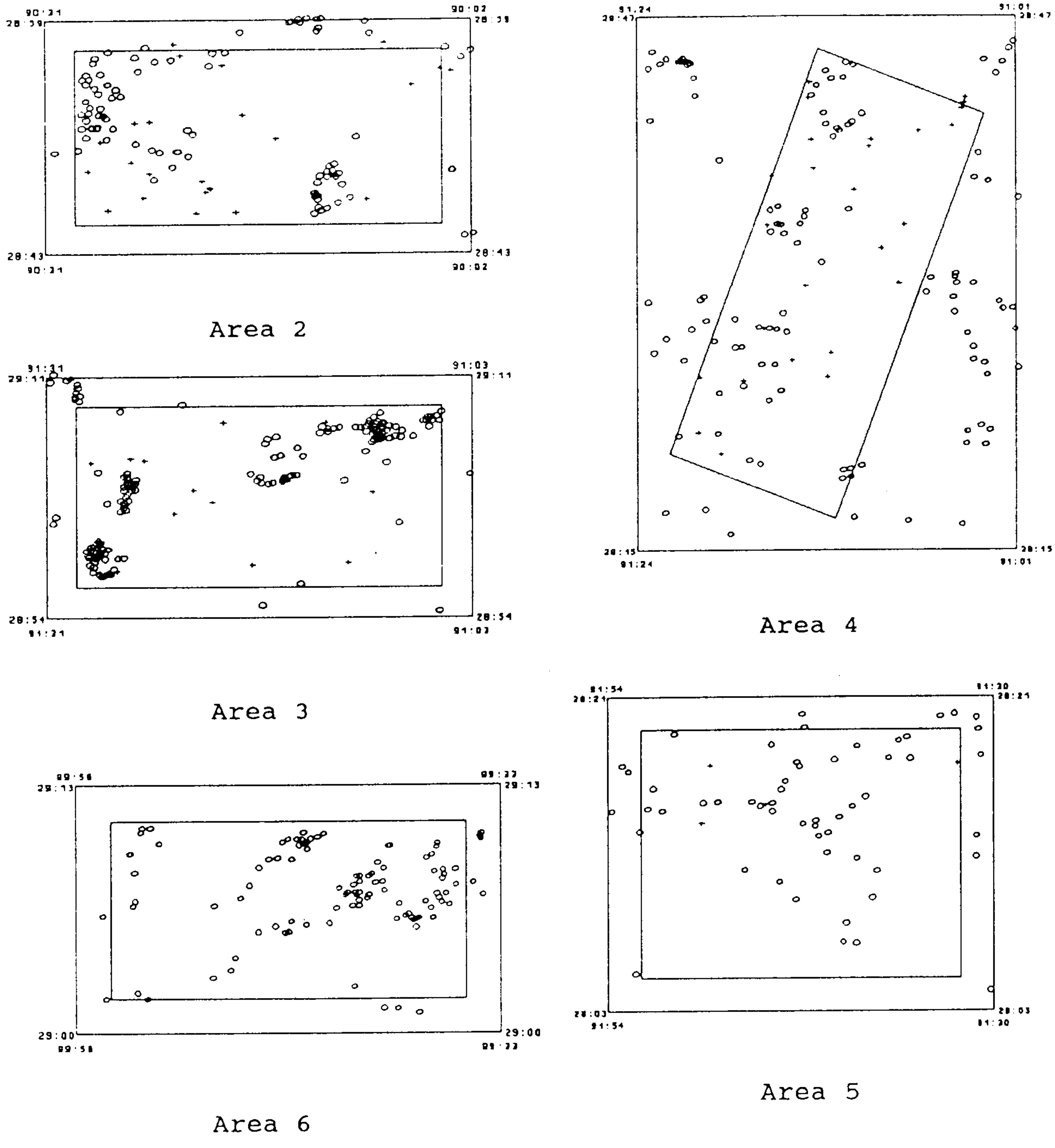


FIGURE 6. LOCATIONS OF PLATFORMS (o) AND SEA TURTLES (+) IN AREAS 2-6.

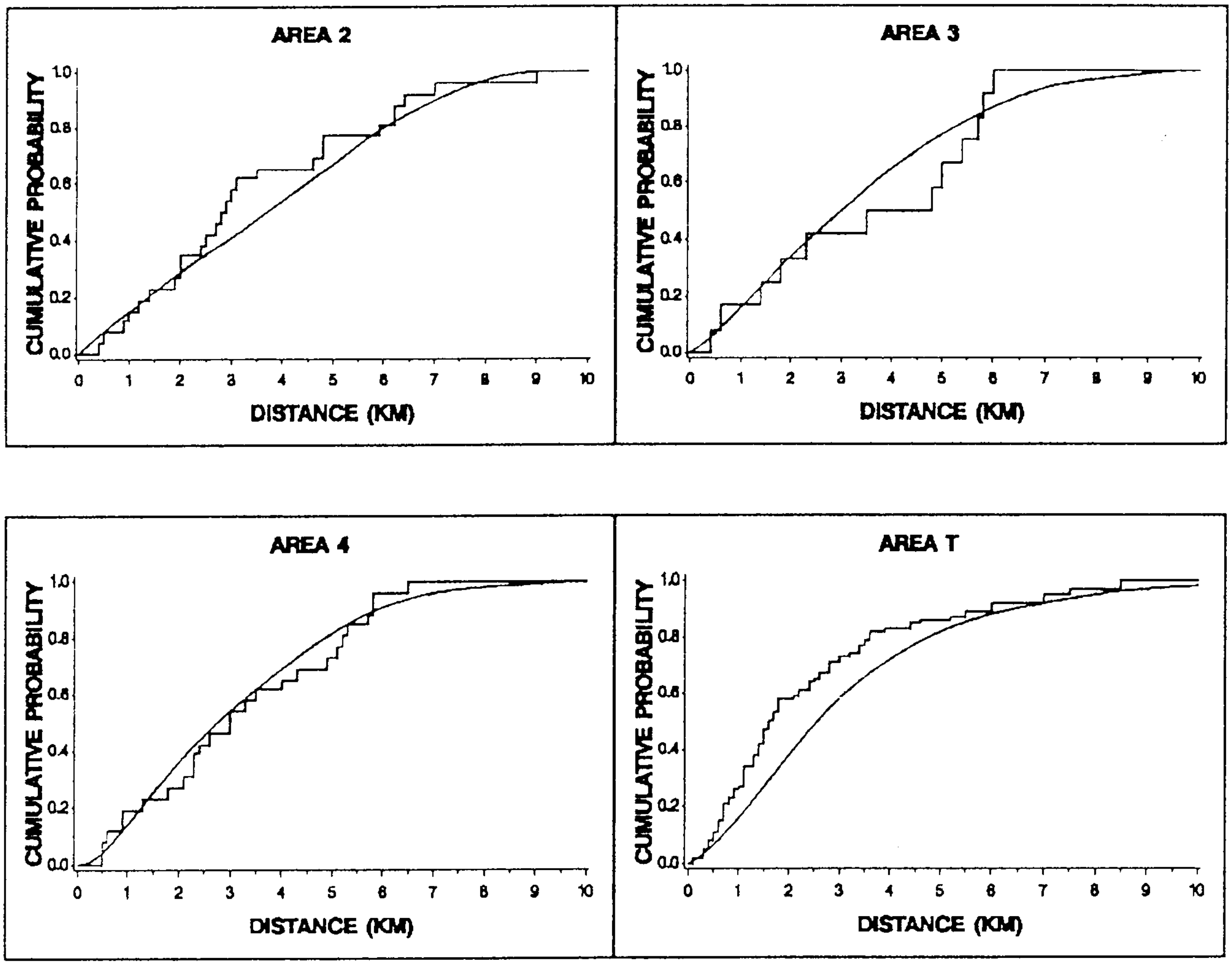


FIGURE 7. HAMILL AND WRIGHT ANALYSIS FOR AREAS 2-4 AND T (observed distribution = step function, expected = continuous).

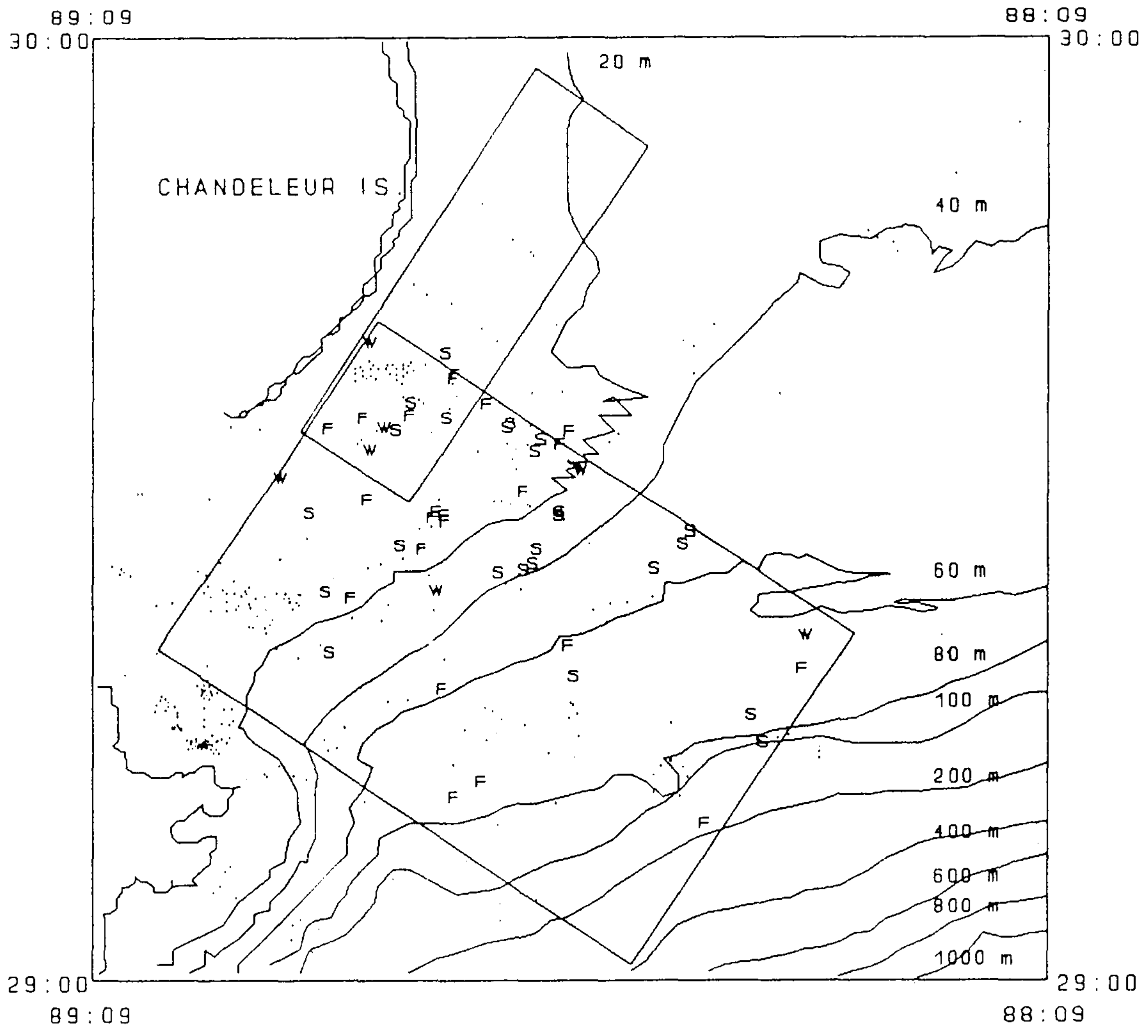


FIGURE 8. LOCATIONS OF SEA TURTLES, PLATFORMS (·) AND ISOBATHS IN AREA T [sea turtles: S - spring, F - fall, W - winter (Area 1, small rectangle, is shown for reference)].

and Figure 7). Fifty-four percent of the sea turtles sighted in Area T were within 2,100 m of a platform.

Correlation Analyses

Generally, the results of the Kendall's rank correlation trials supported the results of the Hamill and Wright's tests. Sea turtles were positively correlated ($P \leq 0.10$) with platforms in six or more trials for each Area 1 data set and for Area T (Table 9). Therefore, in these areas sea turtles were positively associated with platforms. For Areas 2 and 4 there was no significant correlation, therefore the null hypothesis of random sea turtle locations relative to platforms was accepted.

The major differences between the correlation and Hamill and Wright analyses were for Area 3 and for the winter in Area 1. Based on correlation, sea turtles were positively associated with platforms in the winter in Area 1. Eight of the ten trials were significant ($P \leq 0.10$). Because of significant negative correlation in six of ten trials, sea turtles were negatively associated with platform locations in Area 3. These significant results arise in part because of sample size. For both Area T and winter in Area 1, the Hamill and Wright plot reflects the spatial trend that resulted in significant correlation. Because of the small sample of sea turtles sighted in each case (winter Area 1, 22; Area 3, 12) the Hamill and Wright tests were insignificant. However, for the correlation analyses, because the sample size was always 100, (the same sea turtle locations were used often) a significant correlation resulted with a small sample of sea turtle locations in each case.

Chi-square Analyses

The chi-square goodness-of-fit tests also supported the Hamill and Wright test results (Table 10). In Area 1, except in winter, more sea turtles than expected were found in the southern portion of the study area where platforms were also concentrated. This supports the conclusion that sea turtles were positively associated with platform locations in Area 1. In Areas 2, 3, and 4, sea turtle distributions were not significantly different from the expected distributions, even though platforms were significantly concentrated in portions of the study areas. These results support the conclusion that sea turtles in these areas were randomly located with respect to platforms. In Area T, most platforms (79%) were in the western one-half of the study area and more sea turtles than expected were in the western one-half. Too few sea turtles were sighted in Areas 5 and 6 for meaningful analyses.

In summary, for Areas 1 (except for winter) and T, all three tests indicated that sea turtles were positively associated with

TABLE 9. KENDALL'S MEASURE OF RANK CORRELATION TESTS.

	Number of Trials[a]			
	$P > 0.10$		$P \leq 0.10$	
Area	Positive	Negative	Positive	Negative
Area 1				
All turtles	0	0	10	0
"Spring"	0	0	10	0
"Fall"	0	0	10	0
"Winter"	2	0	8	0
Area 2	5	4	1	0
Area 3	0	4	0	6
Area 4	8	0	2	0
Area T	1	0	9	0

a - ten total trials were conducted in each case.

TABLE 10. SEA TURTLE AND PLATFORM CHI-SQUARE TESTS.

Study Area	n	X^2	P
Area 1			
Platforms	57	75.6	$P<0.001$*
All turtles	190	67.1	$P<0.001$*
Jun 88-May 89	152	65.1	$P<0.001$*
Jul 89-Sep 89	44	21.6	$P<0.001$*
"Spring"	82	23.3	$P<0.001$*
"Fall"	48	46.2	$P<0.001$*
"Winter"	22	4.5	$P>0.10$
Area 2			
Platforms	71	52.5	$P<0.001$*
All turtles	26	4.5	$P>0.10$
Area 3			
		(north-south)	
Platforms	147	41.5	$P<0.001$*
All turtles	12	2.0	$P>0.50$
		(east-west)	
Platforms	147	56.7	$P<0.001$*
All turtles	12	3.3	$P>0.10$
Area 4			
Platforms	50	39.9	$P<0.001$*
All turtles	26	2.0	$P>0.50$
Area T			
Platforms	163	93.3	$P<0.001$*
All turtles	55	15.6	$P<0.005$*

n - number of turtles or platforms; X^2 - chi-square
* - significant; P - probability

platforms. From the winter Area 1 data, based on the Hamill and Wright and chi-square test results, we concluded that sea turtles were randomly located with respect to platforms. (Too few sea turtles were sighted in Area T to test the winter platform association.) For Areas 2 and 4, all three tests indicated that sea turtles were randomly located with respect to platforms. For Area 3, only the correlation test was significant. It indicated sea turtles had a significant negative association. However, because only six of ten correlation trials were significant and a small number of sea turtles were sighted, we concluded that sea turtles were randomly located with respect to platforms in Area 3.

Sea Turtle Distributions and Water Depths

Sea turtles in Area 1 and T were not distributed in direct proportion to the area of available water depth categories (Table 11, Figure 9). The distributions of sea turtles in Areas 2, 3 and 4 were not different than expected with respect to available water depths (Figure 10). Too few sea turtles were sighted in Areas 5 and 6 for meaningful tests.

In Area 1, from June 1988 through May 1989, fewer sea turtles than expected were found in water depths greater than 16 m (Table 12). In water less than 11 m deep, the frequency of sea turtles did not differ from the expected, but far more sea turtles than expected were in water from 11-16 m deep. Far more platforms than expected were in water less than 11 m deep, but numbers of platforms were very similar to the expected in water 11-16 m deep. This could indicate that the sea turtles were attracted to a habitat that also happened to be populated by platforms. The same pattern was found when the data were segregated by seasons.

In Area T, most sea turtles were found in water less than 20 m deep (Figure 8). The distribution of sea turtle relative to water depth strata did not appear to change seasonally. While only seven sea turtles were sighted in winter, four were sighted in water less than 20 m deep and only one was sighted in water deeper than 60 m.

In Area 4, while the observed values did not differ significantly from the expected values in water depth categories, more sea turtles were found in water less than 27 m deep. Only five sea turtles were observed in Area 5. All five were in water less than 73 m deep, although these depths comprised slightly less than 50% of the study area.

TABLE 11. SEA TURTLE-WATER DEPTH AND SEA TURTLE-SEDIMENT TYPE CHI-SQUARE TESTS.

		Water Depths		Sediment Types	
Study Area	n	X^2	P	X^2	P
Area 1					
All turtles	190	48.4	P<0.001*	45.6	P<0.001*
Jun 88-May 89	155	49.4	P<0.001*	-	-
Jul-Sep 88	44	14.4	P<0.005*	11.7	P<0.025*
Jul-Sep 89	38	25.8	P<0.001*	11.3	P<0.025*
"Spring"	83	23.6	P<0.001*	29.8	P<0.001*
"Fall"	48	22.5	P<0.001*	17.8	P<0.001*
"Winter"	22	6.8	P<0.10*	5.1	P>0.10
Area 2	26	2.7	P>0.50	0.4	P>0.97
Area 3	12	3.0	P>0.10	-	-
Area 4	26	6.5	P>0.10	2.5	P>0.10
Area T	53	25.4	P<0.001*	-	-

n - number of turtles sighted; X^2 - chi-square
* - significant

TABLE 12. SEA TURTLES AND PLATFORMS IN WATER DEPTH CATEGORIES.

	Sea Turtles		Platforms	
Depth (m)	Observed	Expected	Observed	Expected
Area 1				
<11	43	43	33	15
11-14	63	39	15	13
14-16	39	27	5	9
16-19	7	27	0	9
>19	3	20	0	7

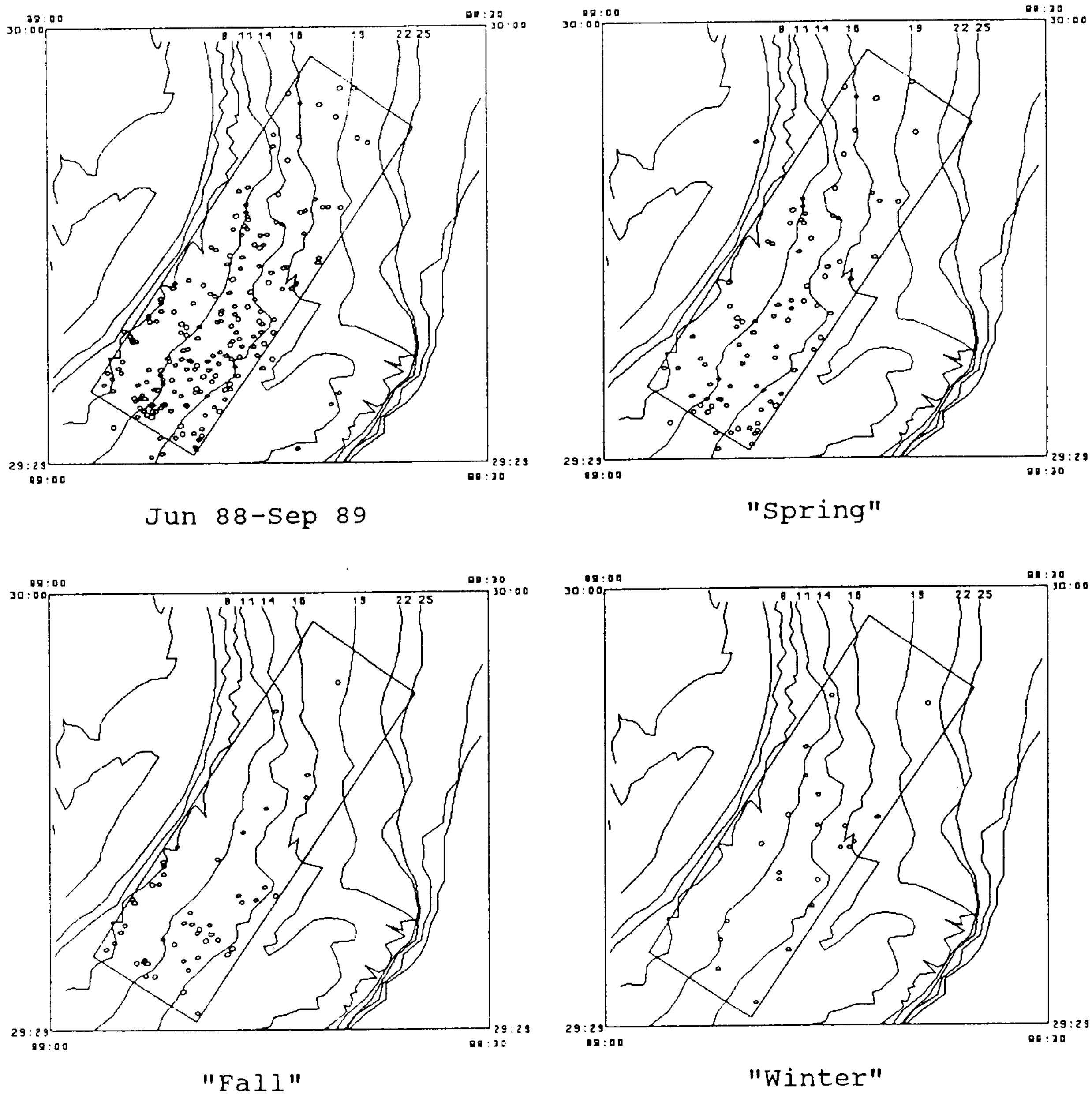
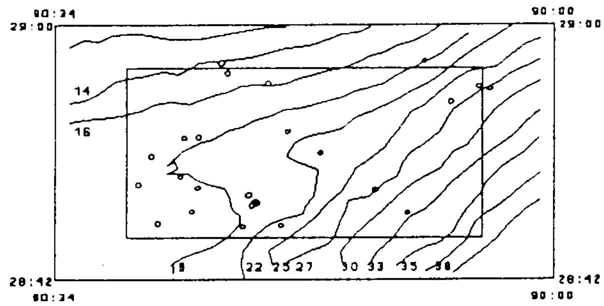
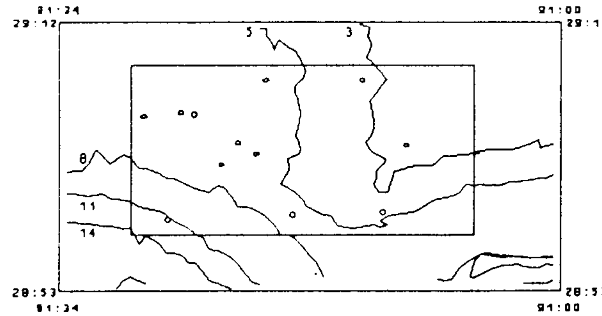


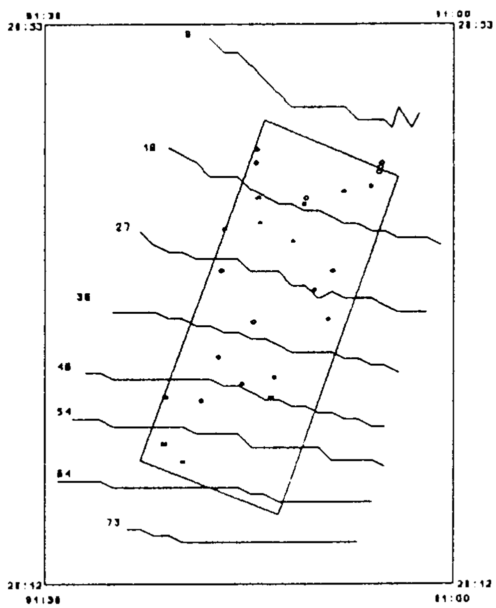
FIGURE 9. SEA TURTLE (o) LOCATIONS AND ISOBATHS (m) IN AREA 1.



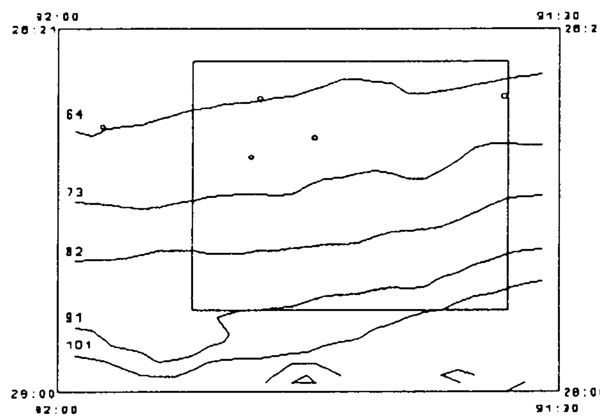
Area 2



Area 3



Area 4



Area 5

FIGURE 10. SEA TURTLE LOCATIONS (o) AND ISOBATHS (m) IN AREAS 2-5.

Sea Turtle and "Hang" Associations

The Hamill and Wright analysis indicated that sea turtles were negatively associated with "hang" locations in Area 1 ($P \leq 0.10$, Figures 11 and 12). The observed distribution approached one at a significantly slower rate than expected. The range of significance for 158 sea turtles sighted from June 1988 through May 1989 was 2,600-5,600 m. Sea turtles were randomly distributed relative to "hang" locations in Areas 2, 3 and 4. Too few turtles were sighted in Area 5 to test for association.

"Hangs" in Area 1 were negatively associated with petroleum platforms ($P < 0.01$). It is likely that trawlers do not drag close to platforms in Area 1, and consequently, do not report "hangs" near platforms. The negative association between "hangs" and sea turtles probably resulted from this and the positive association of sea turtles with the area where platforms were concentrated in Area 1.

Sea Turtle Distributions and Bottom Sediments

In Area 1 chi-square analysis indicated that sea turtles were not distributed randomly or uniformly with respect to estimated areas of sediment types (Table 13 and 11, Figure 13). More sea turtles than expected were found over sandy sediment types. The clays and silts tended to be in the northern portion of the study area and sea turtles were most abundant in the southern portion of the study area. This might indicate that the sea turtles were avoiding these sediment types. However, a sand/silt/clay (mixed) association was in the extreme southern portion of the study area and more sea turtles than expected were over this sediment type.

Sediment types in Areas 2 and 4 did not significantly influence sea turtle distributions, even though both sands and non-sandy sediments were in the areas (Table 11). However, sample sizes were much smaller in these areas. Therefore, while it can not be ruled out that sediment types may affect sea turtle distributions, it is likely that the negative association of sea turtles with silt and clay sediments in Area 1 was coincidental.

The sediment types in Area 3 were uniformly silty, therefore the relationship between sea turtles and bottom sediment types could not be tested. Too few sea turtles were observed in Areas 5 and 6 for meaningful tests.

Water Surface Temperatures and Sea Turtles

Surface sea temperatures ranged from about 16°C in the winter in Areas 1 and 3 to about 24°C in Area 3 in the summer. Surface temperatures remained more constant (about 22-26°C) in Area 5, the

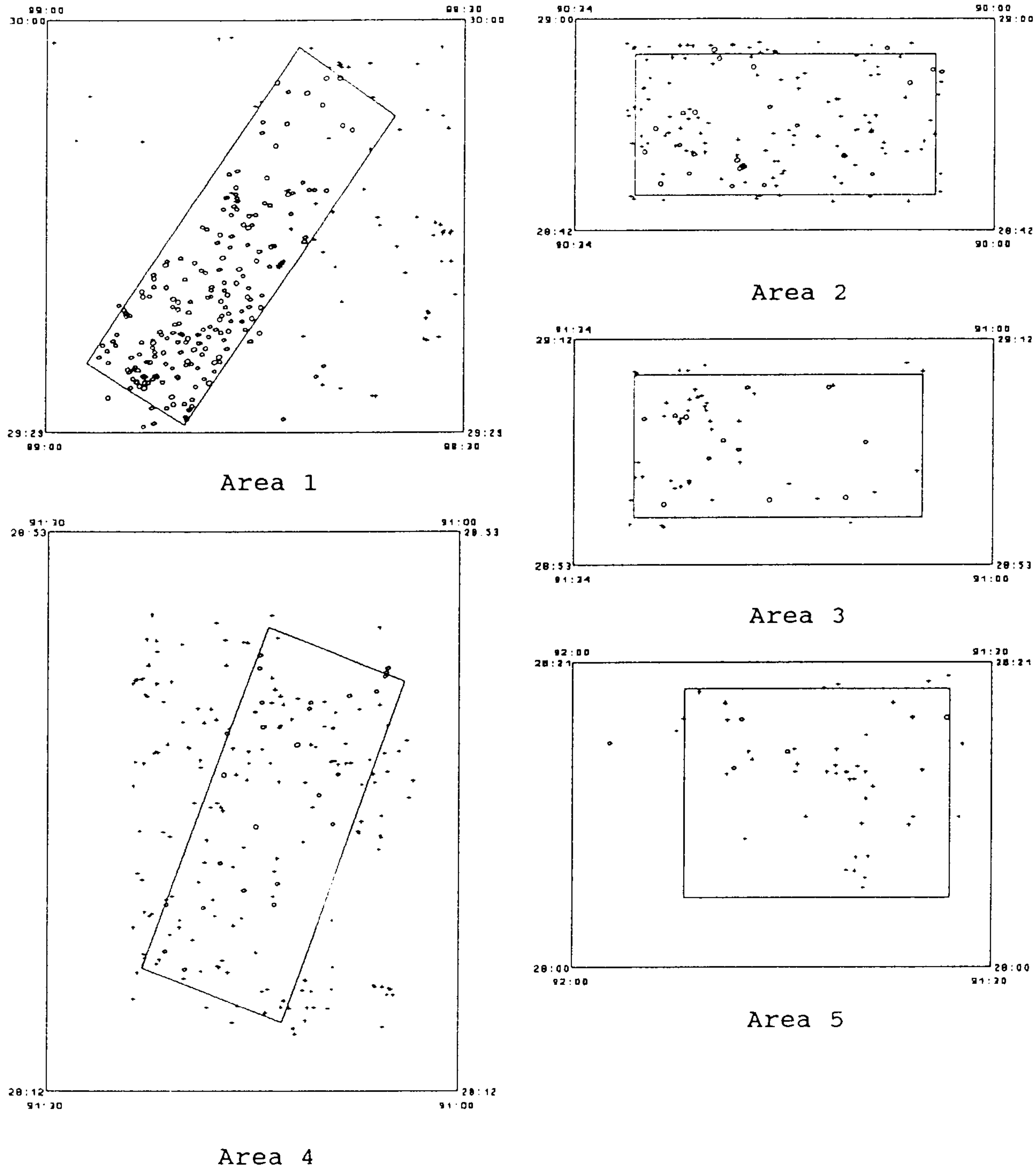


FIGURE 11. LOCATIONS OF SEA TURTLES (o) AND "HANGS" (+).

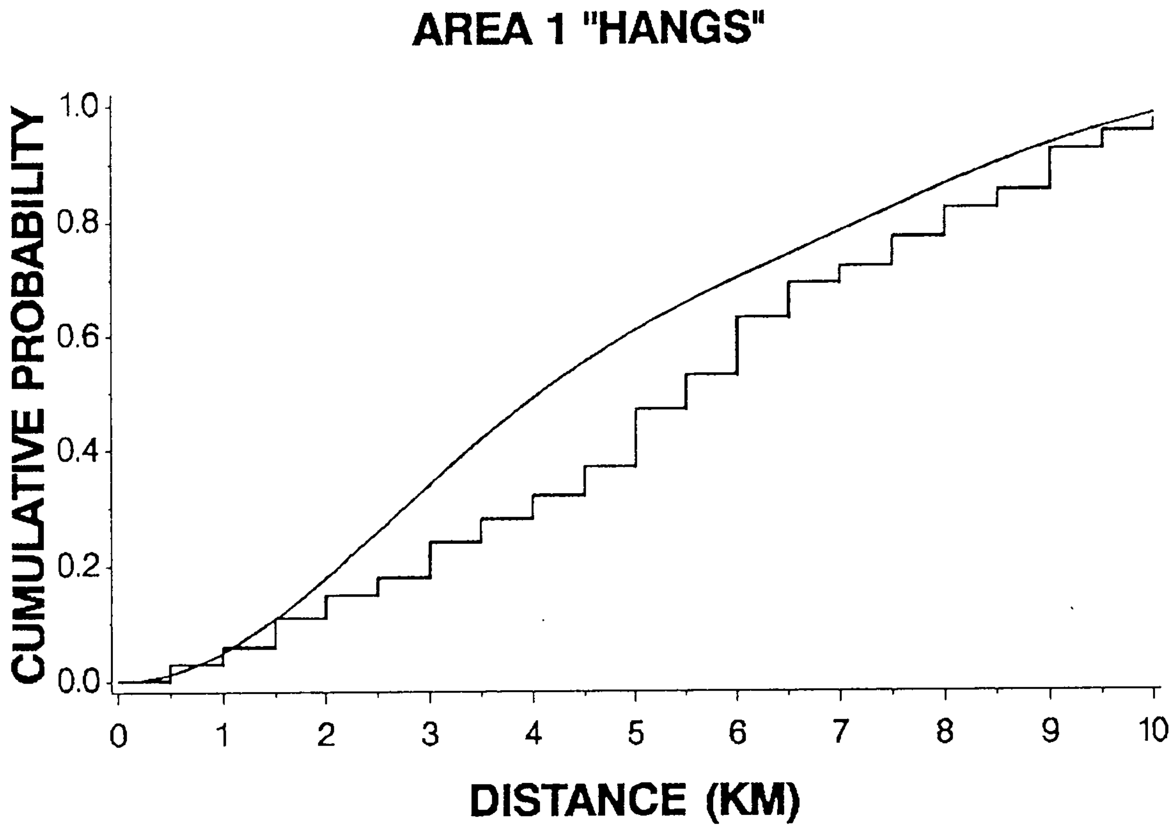


FIGURE 12. HAMILL AND WRIGHT "HANG" ANALYSIS FOR AREA 1 (observed distribution = step function, expected =continuous).

TABLE 13. OBSERVED AND EXPECTED NUMBERS OF SEA TURTLES IN AREA 1 RELATIVE TO SEDIMENT TYPE.

Sediment Type	% Area	Sea Turtles Observed	Sea Turtles Expected
Sands	60.1	152	112
Clays	24.1	17	45
Silts	13.1	8	24
Sand/Silt/Clays	2.6	9	5

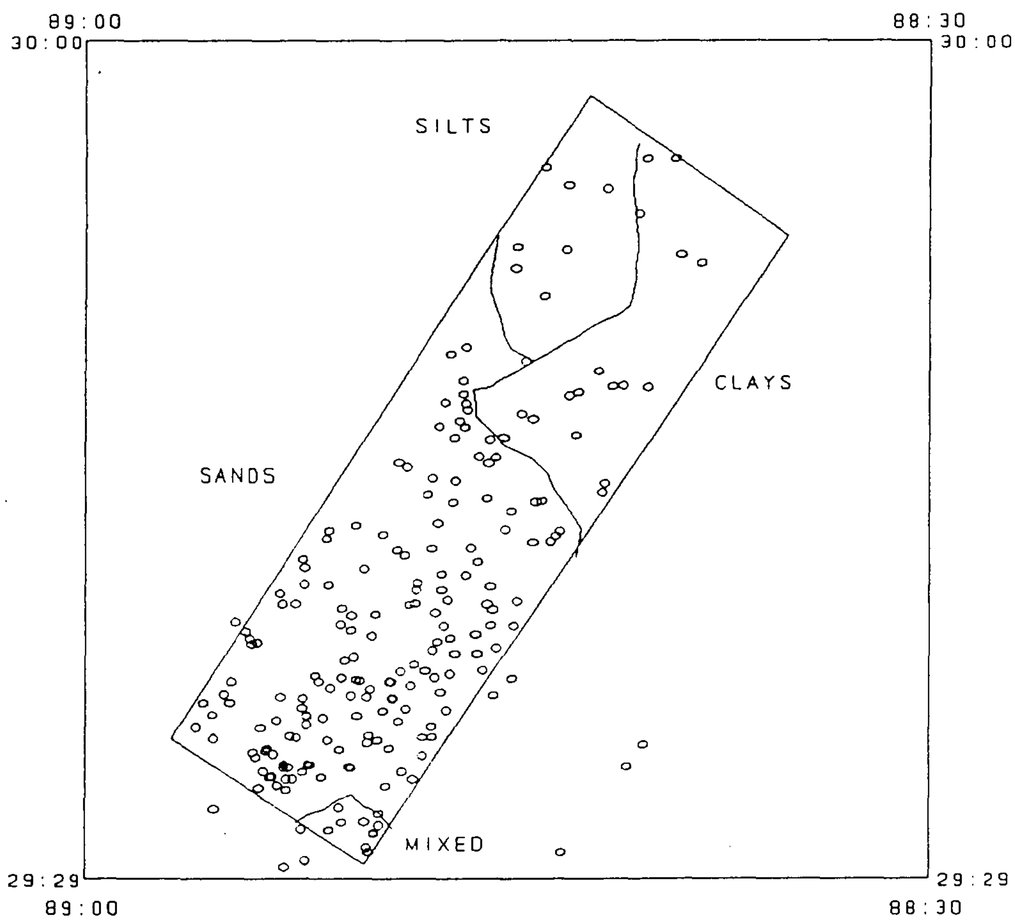


FIGURE 13. SEA TURTLE LOCATIONS (o) AND SEDIMENT TYPES IN AREA 1.

deep water study area. Monthly temperatures in each study area usually varied 1-2°C.

The sighting rates of sea turtles increased from fall to winter in the deeper water areas (Areas 4 and 5) and greatly decreased in more shallow water (Areas 1-3, Table 7). During the winter months, sea turtles were sighted in Area 1 each month (albeit, in reduced numbers), in January in Area 2, and in December in Area 3. Sea turtles were observed in December, February, and March in Area 4, and in December and February in Area 5. The deeper waters tended to stay warmer in winter and sea turtles might have gone there if they were avoiding cold water.

In February and March 1989, some loggerheads sighted in Area 1 were observed with mud trails flowing from their carapaces. This suggested that they have been buried in the sediments. Since loggerheads were observed in Area 1 throughout the winter, it is likely that some turtles over-wintered in this area and may have brumated in the bottom sediments.

Sea Turtle-Platform Distance Probabilities

In Habitat Zone 1, the probability that one or more sea turtles were within 1,000 m of any randomly selected platform was great, more than 50% (Table 14). When calculated separately for each season, the probabilities that sea turtles were within 1,000 m of a platform decreased, but were still great, ranging from about 67% in the fall to about 10% in the winter. It must be emphasized that the reduced numbers of winter sea turtles, and the consequent reduction in probabilities, was based on the density of surfaced sea turtles. Sea turtles may be simply spending less time at the surface in the winter and the probabilities of a brumating turtle being near a platform may be much greater than this model indicates.

In the Habitat Zones west of the Mississippi River the probabilities were less than in Habitat Zone 1. In Habitat Zones 2 and 4, the probabilities were similar. The probability that sea turtles were within 1,000 m of any randomly selected platform was estimated to be about 7%. Because sea turtles were less commonly sighted in very shallow (Area 3) and deeper water (Area 5), in Habitat Zones 3 and 5, the probability that sea turtles were within 1,000 m of any randomly selected platform was much less, about 2-3%.

We reemphasize that these estimates are only for large sea turtles, primarily large loggerheads (about 70 cm or greater in carapace length), and do not account for the probability that a juvenile sea turtle was within some distance of a platform. This is especially true for Area 3 where the water was usually very

TABLE 14. SEA TURTLE-PLATFORM DISTANCE PROBABILITIES.

		Probability			
		Number of Sea Turtles			
Distance (m)	Number of Sea Turtles	0	1	2	>2
Habitat Zone 1					
All Seasons					
500	64	.79	.19	.02	0
1,000	234	.42	.37	.16	.05
1,500	302	.32	.36	.21	.11
2,000	426	.20	.32	.26	.22
"Spring"					
500	96	.70	.25	.04	.01
1,000	305	.32	.36	.21	.11
1,500	385	.24	.34	.25	.17
2,000	528	.14	.27	.27	.32
"Fall"					
500	75	.76	.21	.03	0
1,000	301	.33	.37	.21	.09
1,500	377	.24	.34	.24	.18
2,000	566	.12	.26	.27	.35
"Winter"					
500	14	.95	.05	0	0
1,000	28	.90	.09	.01	0
1,500	28	.87	.09	.04	0
2,000	71	.77	.20	.03	0
Habitat Zone 2					
500	21	.98	.02	0	0
1,000	64	.93	.07	0	0
1,500	111	.88	.11	.01	0
2,000	154	.84	.15	.01	0

continued

TABLE 14. CONTINUED

		Probability			
		Number of Sea Turtles			
Distance (m)	Number of Sea Turtles	0	1	2	>2
Habitat Zone 3					
500	13	.99	.01	0	0
1,000	28	.98	.02	0	0
1,500	43	.97	.03	0	0
2,000	58	.96	.04	0	0
Habitat Zone 4					
500	21	.98	.02	0	0
1,000	78	.93	.07	0	0
1,500	134	.88	.11	.01	0
2,000	191	.84	.15	.01	0
Habitat Zone 5					
500	1	.99	.01	0	0
1,000	3	.97	.03	0	0
1,500	6	.95	.05	.01	0
2,000	9	.92	.07	.01	0

turbid and no underwater sea turtles were sighted (underwater sightings were an important component of total sightings in the other study areas). Also, sightings of juvenile Kemp's ridley sea turtles in Habitat Zone 3 (Area 3) may have been prevented because of their drab color and small size. The shallow waters of the Louisiana coast (Habitat Zone 3) may be one of the primary foraging grounds of juvenile Kemp's ridleys.

Platforms with Associated Sea Turtles

Only in Area 1 were sea turtles positively associated with platforms. In the other study areas sea turtles were randomly located relative to platform locations. Because we had a sufficiently large sample size in Area 1, we wanted to determine if sea turtles were simply associated with platforms in general or if the association was with specific platforms. However lack of association overall between platforms and sea turtles in the other areas does not preclude the possibility that a particular platform had one or more sea turtles associated with it. Therefore, we examined every sea turtle sighting in each study area, identified the nearest platform to each sea turtle and calculated the distance from the platform to the sea turtle. For all sea turtle sightings and for all platforms, in the distance intervals, 0-500, 0-1000, 0-1500 m, we counted the number of sea turtles in each interval and estimated the probability of that number of sea turtles being within that interval. If the probability was significant ($P \leq 0.10$), the platform was labeled a "nearest" platform. The "nearest" platforms were then profiled and compared to the profile of the "other" platforms in the study area.

In Area 1, eighteen different platforms were the nearest platform to sea turtles more often than would be expected by chance ($P \leq 0.10$) in one or more distances categories (Table 15). All but one of the platforms were located in the southern portion of Area 1 (Figure 14). Eight of the platforms were nearest platform at 500 m, ten at 1,000 m, and eleven at 1,500 m.

Fifteen of these 18 platforms were cross-referenced to the MMS data base and profiled (Table 16). Their profile was compared to the profile of the 41 other platforms in the MMS data base that also occurred in Area 1. The "nearest" platforms tended to be minor platforms whereas the "other" platforms were nearly equally divided between minor and major platforms. Only one (7%) of the "nearest" platforms was manned but eight (20%) of the "other" platforms were recorded as manned. This might reflect a difference in production areas as the "nearest" platforms had a higher percentage of platforms that produced natural gas and fewer that produced oil. Overall, "nearest" platforms tended to be smaller,

TABLE 15. PLATFORMS WITH MORE SEA TURTLES THAN EXPECTED NEAR THEM.

			Nearest Platform to a Sea Turtle					
			500 m		1,000 m		1,500 m	
ID	PID	t	n	P	n	P	n	P
1480001	A	16	2	0.14	8	<0.01	9	<0.01
1480002	B	10	1	0.31	4	0.02	6	0.01
1310004	C	8	1	0.29	3	0.06	4	0.06
1310006	D	8	0	0.68	0	0.34	4	0.06
1610006	E	8	1	0.29	4	0.01	5	0.01
1560004	F	6	0	0.74	2	0.14	3	0.10
1660003	G	4	0	0.82	2	0.07	2	0.18
1660005	H	3	1	0.13	2	0.04	2	0.11
1020000	I	2	1	0.09	2	0.02	2	0.05
1560005	J	2	0	0.91	2	0.02	2	0.05
1560008	K	2	0	0.91	1	0.22	2	0.05
1610005	L	2	2	<0.01	2	0.02	2	0.05
1660002	M	2	1	0.09	2	0.02	2	0.05
1020001	N	1	1	0.05	1	0.13	1	0.22
1030005	O	1	1	0.05	1	0.13	1	0.22
1560007	P	1	1	0.05	1	0.13	1	0.22
1560003	Q	1	1	0.05	1	0.13	1	0.22
1610002	R	1	1	0.05	1	0.13	1	0.22

ID - USCG identification number; PID - identifier in Figure 14; t - number of times the platform was the nearest platform to a sea turtle; n - number of times a sea turtle was within the distance; P - binomial probability of that number of sea turtles being within the distance interval

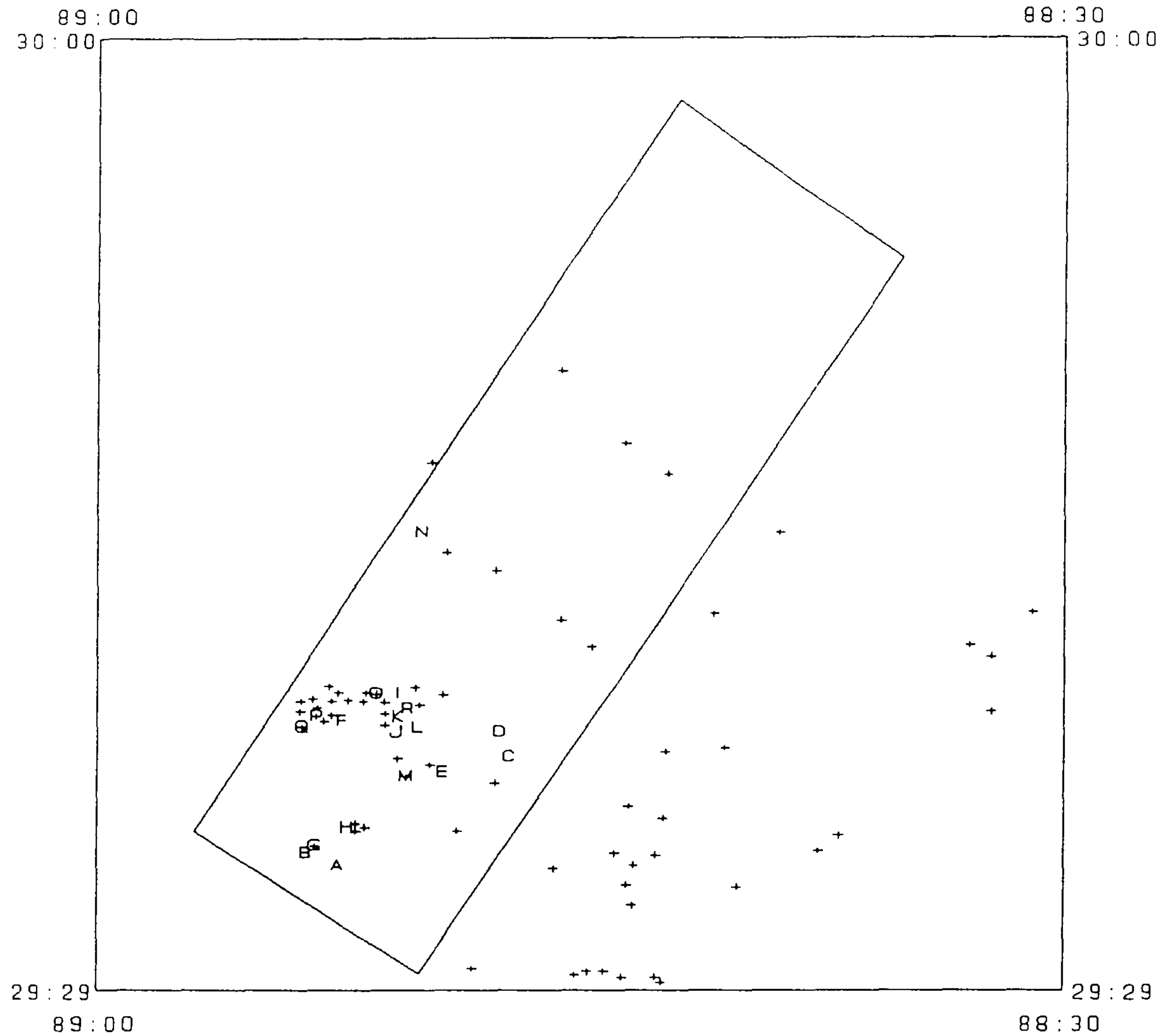


FIGURE 14. LOCATIONS OF "NEAREST" PLATFORMS (A-R) AND "OTHER" PLATFORMS (+) IN AREA 1.

TABLE 16. COMPARISON OF "NEAREST" AND "OTHER" PLATFORMS IN AREA 1.

Data Type	Nearest Platforms	Other Platforms
Sample Size	15	41
Average Distance to Shore (km)	42.2 (9.6)	45.1 (13.0)[a]
Average Water Depth (m)	12.4 (3.4)	13.8 (3.7)
Average Year of 1st Production	1973	1975
Average Number of Decks	1.4 (0.5)	1.6 (0.7)
Average Number of Slots	1.1 (0.7)	1.4 (1.4)
Average Number of Drilled Slots	1.1 (0.7)	1.3 (1.1)
Percent Manned	7	20
Percent Unmanned	93	80
Percent Major Platforms	20	46
Percent Minor Platforms	80	54
Percent Produce Natural Gas	100	93
Percent Produce Natural Oil	7	17
Percent Produce Water	0	15
Percent Produce Condensate	13	44

a - standard error

unmanned, produced natural gas, and were closer to shore than the "other" platforms in and near Area 1. For the other variables examined there was very little difference between the "nearest" and "other" platforms in Area 1.

In Area 2, 21 platforms were the nearest platform to a sea turtle. Only one platform had more turtles than expected within a specified distance. Platform USCG 1120034 had two sea turtles within 500 m ($P < 0.003$). This platform was about 27 km offshore in water about 26 m deep. It was not manned and was not considered a major structure, with only 1 deck and 4 drilled slots. It produced gas and condensate and the first year of production was 1967.

In Area 3, eight platforms were the nearest platform to sea turtles. Only one distance association was significant ($P = 0.07$), one turtle identified as either a Kemp's ridley or green sea turtle was observed within 300 m of USCG platform 1060019. This platform was about 43 km offshore in water about 10 m deep. It was not manned and was not considered a major structure. It had 2 decks and 1 drilled slot. It was not recorded as currently productive and the first year of production was 1959.

In Area 4, 23 platforms were the nearest platform to sea turtles and two platforms had sea turtles sighted within 500 m ($P = 0.046$). One platform (USCG 1500005) had a loggerhead within 500 m. This platform was about 82 km from shore in water about 45 m deep. The platform was judged to be a major structure but was not manned. It had 2 decks and 18 slots, 13 of which were drilled. It was recorded as producing both gas and oil and the year of first production was 1978.

A sea turtle identified as either a Kemp's ridley or green sea turtle was sighted about 410 m from USCG 1960029 in Area 4. This unmanned major platform was about 50 km from shore in water about 16 m deep. The platform had 2 decks and 4 slots, 3 of which were drilled. The platform was not recorded as currently productive and had been first productive in 1955.

In Area 5, one loggerhead was sighted about 470 m from USCG 1440002. This major platform was manned. It was about 118 km from shore in water about 72 m deep. The platform had 2 decks and 18 drilled slots. It was recorded as being first productive in 1975 and produced gas, oil, water, and condensate.

Leatherback Sea Turtles

From June 1988 through June 1990, 86 leatherbacks were sighted. Leatherbacks were sighted in all study areas except Area 3, Block 6 and Block 7 (Figure 15, see Figure 2). Twenty-one leatherbacks were sighted in Area A from September-October 1989. Eighteen were sighted in Area 7 and 14 in Area 8. Sixty-four (74%)

of the leatherbacks sightings were made from July-November in 1989. Twenty-four leatherback sightings occurred in waters less than 100 m deep (Areas 1-6 and T).

Too few leatherbacks were sighted to test for association with petroleum platforms or "hangs." One leatherback in Area 6 was observed less than 1,000 m from a petroleum platform. Six leatherbacks were within 1,000-2,000 m of a platform. At distances of 2,000-5,000 m from platforms, eight leatherbacks were sighted and six were sighted from 5,000-8,000 m.

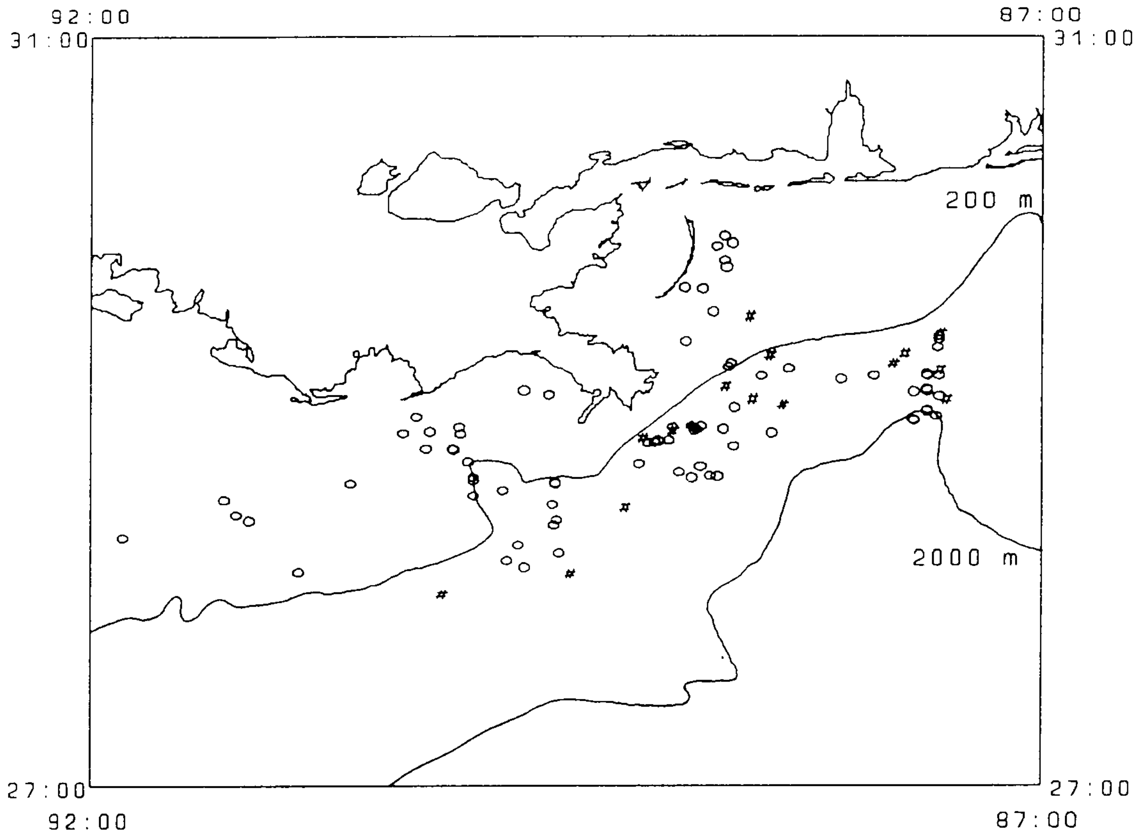


FIGURE 15. LOCATIONS OF ALL LEATHERBACKS SIGHTED (o) AND DEEP WATER CHELONID SIGHTINGS (#).

DISCUSSION

Species Identification

Large loggerhead sea turtles are easy to identify from aerial surveys. When surfaced, they are reddish-brown in color. If visible, their heads are noticeably large. In July 1989, we acquired ground truth data for our loggerhead identifications. We used aircraft to locate sea turtles for capture by a purse seine boat. Seven sea turtles were captured and were independently identified as loggerheads by air and surface based personnel. However, when swimming below the surface of the water, the distinctive color of the loggerhead can not be observed. Although most submerged sea turtles sighted "through water" were probably loggerheads, they were recorded as unidentified chelonids.

We do not have ground truth data for green, Kemp's ridley, or hawksbill sea turtles. Adult green sea turtles are considerably larger than Kemp's ridleys or hawksbills. When we observed a very large turtle that was not a loggerhead, we identified it as a probable green sea turtle. Occasionally we observed smaller sea turtles that had roundish and gray-colored carapaces. We believed these turtles were probably Kemp's ridleys. During this study we did not observe any sea turtles that we thought were hawksbills. However, in past surveys, usually offshore of southern Florida, we have observed sea turtles we recorded as hawksbills (Lohoefener et al. 1988). These turtles had dark brownish-colored and somewhat elongated carapaces. Leatherback sea turtles, because they are large and distinctively colored and shaped, are easy to identify from aerial surveys.

Generally, except under unusual sighting conditions, only large sea turtles can be observed from aerial surveys. The shallow waters offshore of Louisiana are believed to be a major foraging area for both adult and subadult Kemp's ridleys (Liner 1954, Dobie et al. 1961, Viosca 1961). The size of stranded Kemp's ridleys we have observed, and those captured in shrimp trawls (Henwood and Stuntz 1987), are often described as having carapaces the size of "dinner-plates." It is very improbable that these turtles could be reliably observed from aerial surveys, especially in the turbid water offshore of Louisiana. Therefore, the results of this study do not allow us to speculate on the spatial distribution of juvenile sea turtles with respect to petroleum platforms.

Sources of Bias

We used line transect methods (Burnham et al. 1980) to make seasonal and annual estimates of sea turtle density. We used density estimates to assess the probability that a sea turtle was near a platform. Four assumptions form the foundation of line transect density estimation: (1) sea turtles on or very near the transect line area were always observed, (2) sea turtles were not counted twice, (3) perpendicular distances were measured accurately, and (4) sea turtle sightings were independent events.

Our study probably violated assumptions one and three. An unknown number of sea turtles that were on the surface and on or very near the transect line were probably not sighted. The high resolution video camera recorded the surface of the water on and very near the transect line. However, even with the high resolution, because of the relatively small size of the sea turtles, the motion of the water past the camera, the common presence of waves, and glare on the water, very few sea turtles were identifiable on the video record. Those that were identified were also sighted by an observer. However, sea turtles were probably missed because the video record did indicate that we missed seeing other, even larger, marine animals (e.g., bottlenose dolphins) that were on or near the transect line. This is not a surprising result. Jolly (1969) noted that even the best of observers, in the best of conditions, sometimes miss observing obvious animals. Since we missed sighting at least three bottlenose dolphin herds, it is reasonable to assume we also missed sighting some sea turtles. As a result, we probably underestimated the density of sea turtles by an unknown degree.

We used an inclinometer to measure the angle to each sea turtle sighting. This angle was used to calculate the perpendicular distance from the transect line to the sea turtle. As the angle increased the perpendicular distance represented by a degree of angle increased. Because of this, our ability to measure accurately distances perpendicular to the transect line decreased as the perpendicular distance to the sea turtle increased. This violation should not have important ramifications with regard to the accuracy of our density estimates for three reasons: (1) comparatively few sea turtles were sighted at perpendicular distances greater than 300 m (Figure 3); (2) we grouped our sighting distance in 100 m increments; and (3) the probability of underestimating the distance should have been the same as that of overestimating the distance. Therefore, the true sighting distance should have assumed the characteristics of a random variable within some range.

All of the models used to estimate $\hat{f}(0)$, except the Hermite models with three and four parameters, tended to underestimate the observed $\hat{f}(0)$ by a small degree (Table 3 and Figure 3). We did not accept the visual goodness-of-fit for the two Hermite models because they lacked a sighting "shoulder" or plateau near the transect line and they slightly overestimated the observed $\hat{f}(0)$. Therefore, we may have slightly underestimated $\hat{f}(0)$. Consequently, along with missing some sea turtles on or very near the transect line, we probably underestimated the density of sea turtles. As an end result, we almost certainly underestimated the probability of a sea turtle being within some distance of a platform. Because the probability of not observing a sea turtle on or near the transect line should not have been affected by the seasons, this source of bias should not have affected seasonal comparisons of sea turtle abundance.

Our study might have also been biased if sea turtles associated with platforms surfaced within the confines of the structure, or perhaps, even very near to the platform supports. This might have increased the likelihood of our missing the sea turtles. Conversely, the platforms gave us a focus point for observations and we probably concentrated more on the water near a platform than the surrounding water. This would have biased our results in favor of sighting sea turtles near platforms. We can not assess the magnitude of these two sources of possible bias. Our observations, from both aircraft and surface vessels, and anecdotal observations related to us by recreational and commercial fishermen that regularly tie up to the platforms to fish, suggest that during daylight hours sea turtles do not surface within the support structures of the platform nor alongside the platform. Rather, they surface some distance away from the platform. However, the presence of the boat could affect the surfacing behavior of sea turtles.

Another possible source of bias would be if a sea turtle near an oil platform surfaced more often or stayed a longer period of time on the surface than a sea turtle not near a platform. Then the results would be biased to favor an association between platforms and sea turtles. Conversely, if a sea turtle surfaced less regularly or spent less time on the surface when near a platform, then the opposite would be true. This possible source of bias can not be evaluated without a comparative study of sea turtle behavior between sea turtles associated and not associated with platforms.

Relative Abundance of Sea Turtles

We found sea turtles to be far more abundant east of the Mississippi River (offshore of the Chandeleur and Breton Islands) than they were in the five study areas west of the river. Depending on the study area west of the river considered, we found sea turtles offshore of the Chandeleur and Breton Islands were about 6 to 30 times more abundant than sea turtles west of the river. These results, in terms of trend, agreed with our 1987 aerial survey results (Lohoefener et al. 1988). During our spring and fall 1987 surveys for red drum schools, we recorded all sea turtles sighted and used strip-transect methods to estimate the abundance of sea turtles. In the 1987 study, east of the river to Perdido Bay, Alabama, we found sea turtles were about 4 to 6 times more abundant than from west of the river to Sabine Pass, Louisiana. The maximum density of sea turtles estimated in 1987 was 0.3 sea turtles/100 km^2.

Our estimates for the western study areas are similar to the overall estimate made by Fritts et al. (1983). They studied an area further west offshore of Louisiana during June, August, October, February, and April 1980 and 1981. Overall, they estimated 0.21 loggerheads/100 km^2. Depending on study area, we estimated the average density of sea turtles west of the river range from about 0.11 to 0.50 sea turtles/100 km^2.

We do not know why sea turtles, most of which were probably loggerheads, were so much more common east of the river, offshore of the Chandeleur and Breton Islands. Although sea turtles were positively associated with platforms east of the river (see below), we doubt that the presence of platforms draws large numbers of loggerheads into the area. Petroleum platform concentrations are found throughout the north-central Gulf in nearshore habitat without a corresponding abundance of loggerheads.

Loggerheads may have been largely extirpated in other similar habitats in the north-central Gulf and the loggerheads off Chandeleur and Breton Islands are a surviving population. Historically, loggerheads nested all along the Mississippi barrier islands, the Chandeleurs, and Grande Isle, Louisiana (Viosca 1961). Now, loggerheads are rarely observed nesting on the Mississippi barrier islands and no loggerheads are known to nest on Grande Isle. During our July through September 1989 aerial surveys, we did not sight any sea turtles offshore of Grande Isle.

Based on the number of nests and crawls observed in July 1989, we believe that more than 200 loggerheads may be nesting on Chandeleur and Breton Islands. Fuller and Lohoefener (1990) estimated that 1,200 loggerheads might be just offshore of Breton and Chandeleur Islands during the nesting season. We do not know if the Chandeleurs, as a nesting beach for loggerheads, could solely account for the greatly increased abundance of sea turtles in this area. This area may have preferred nesting habitat, water depths, bottom sediments and/or prey species that cause the loggerhead population to be abundant compared to other north-central Gulf locations (see below). Data from October 1989 to June 1990, for the larger study area offshore of Chandeleur and Breton Islands (Area T, Figure 8), indicate that sea turtles were also abundant, compared to areas west of the river, in the deeper waters (especially from 20-60 m) offshore of the original study area (Area 1).

Sea Turtle-Platform Associations

How are sea turtles distributed spatially relative to platforms? To briefly recapitulate our results, three different types of statistical tests all indicated that sea turtles had a significant positive association with platforms east of the Mississippi River (Areas 1 and T). However, the same tests indicated that sea turtles were randomly located with respect to platform locations in study areas west of the river. We estimated that the probabilities of at least one sea turtle being within 500 m of a platform ranged from about 30% in Habitat Zone 1 (spring season) to only 1% in Habitat Zones 3 and 5. At 2,000 m, we estimated these probabilities ranged from about 86% in Habitat Zone 1 (spring season) to about 4% in Habitat Zone 3.

Are sea turtles attracted to petroleum platforms? There is no doubt that some loggerheads take up residence, at least briefly or seasonally, at specific platforms or other hard bottom structures (Caldwell et al. 1955, Hastings et al. 1975, Rabalais and Rabalais 1980, Fuller and Tappan 1986, O'Hara and Wilcox 1987, Rosman et al. 1987, Gitschlag and Renaud 1989, Limpus 1989, L. Ogren pers. comm.). Except for hawksbills associated with reefs, almost all observations of sea turtles associated with underwater structures have been of loggerheads. However, Fuller and Tappan (1986) reported a dead leatherback entangled in cable beneath an oil platform offshore of Louisiana. Also, recent information (S. Stevens, pers comm.) indicates that some platforms are more attractive to loggerheads than other platforms.

In Area 1 we identified 18 platforms that may have had associated sea turtles on a regular basis. We compared characteristics of these platforms to platforms in the same area that did not seem to attract sea turtles (Table 16). Only two major differences were evident: (1) the platforms with associated sea turtles tended to be smaller (minor platforms) and (2) more were unmanned. Several of the 18 platforms were in the midst of clusters of platforms (Figure 14), so it is unlikely that the location of the platforms (i.e., as outliers or isolated platforms) affected these results. Research is needed to understand what characteristics, if any, serve to attract sea turtles to specific petroleum platforms.

For the five study areas (Areas 2-6) west of the river, the fact that sea turtles were found to be randomly located with respect to platform locations cannot be interpreted to mean that one or more sea turtles could not be attracted to a specific platform or a particular platform type. What our results do indicate, unlike the situation in Areas 1 and T, is that there was not a general association between sea turtles and petroleum platforms. Our results in Areas 1 and T indicated at least a general association, and likely platform-specific associations, of at least some sea turtles with petroleum platforms.

Analysis of the relationship between the spatial distribution of sea turtles and water depth in Area 1 indicated that presence of platforms may not be a dominant factor explaining sea turtle distribution. When we compared the number of sea turtles to the number of petroleum platforms in Area 1 by water depth (Table 12), far more turtles than expected were in water from 11-16 m deep. However, far more platforms than expected were in water less than

11 m deep. This suggests that water depth explains the spatial distribution of sea turtles better than the distribution and abundance of platforms.

Although platforms may not be a dominant factor affecting the distribution of sea turtles east of the river, where sea turtles and platforms were in the same general location, sea turtles were positively associated with platforms. When the southern one-third of Area 1 alone was examined, sea turtles were still positively associated with platforms. In Area T (Figure 8) many of the sea turtles sighted were aggregated in water less than 20 m deep near a concentration of platforms in the northwest portion of the study area. However, 34% of the sea turtles were sighted in deeper water where platforms were less concentrated and the significant positive association of sea turtles with platforms in Area T was still maintained. This indicates that outside of the main concentration of sea turtles and platforms, sea turtles were probably still associated with platforms.

Fritts et al. (1983) reported that the majority of loggerheads they observed in all study areas were in water less than 50 m deep. Our results generally supported their findings. Sea turtles were rarely observed in Area 5, where all water depths were greater than 50 m, and fewer sea turtles than expected were observed in Area 4 when water depths exceeded 46 m. However, in Area T, 24% of all sea turtles sighted were in water depths near or greater than 50 m (Figure 8). In the deep water study areas (>200 m), 15 loggerheads or unidentified chelonids were sighted. Some of these were in waters exceeding 1,000 m in depth.

Analysis of the spatial distribution of sea turtles and sediment types in Area 1 indicated that sediment type could also explain the distribution of sea turtles in Area 1. Area 1 had predominately sandy sediments (Figure 3) in the southern two-thirds of the study area (also the area most heavily populated by platforms). Significantly more sea turtles than expected were observed over the sandy sediments. However, three factors must be considered when interpreting the sediment-sea turtle relationship in Area 1. (1) Sandy sediments also occurred in Areas 2 and 4, but there was not a detectable increase in abundance of sea turtles over the sandy sediments. (Albeit, the relatively small sample sizes of sea turtles in these two study areas might have prevented us from detecting a sediment association.) Sea turtles were also more common over a small area of sediments classed as "mixed" in the extreme southeastern corner of Area 1. (2) Sediment types were classed as predominately sandy, silty, etc. However, there is very little actual difference in particle composition between a sandy-silt and a silty-sand, which would have been classed, respectively, as a sandy and a silty sediment. (3) The NMFS sediment data base (Benton and Thompson 1988) is based on relatively few core samples and requires considerable interpolation between points. The lines we used to delineate sediment types in Area 1 could, based on individual interpolations, have been drawn in different configurations that might have altered the results. The distribution of sea turtles offshore of Breton and Chandeleur Islands with respect to bottom sediment types warrants more research with a bottom sediment data base of greater resolution.

Bottom sediments could greatly influence the nearshore distribution of loggerheads. Dodd (1988), in an excellent synopsis of the biological data on loggerheads, summarized the wide range of prey known for loggerheads. He noted that adult loggerheads are usually benthic foragers, generally carnivorous, and tend to prefer mollusks. Dodd (1988) noted that loggerheads may use a locally abundant prey and noted that one preferred prey in the southeastern United States was the horseshoe crab (Limulus sp.).

Plotkin (1989) examined 82 stranded large loggerheads from southern Texas. She also reported that large loggerheads were predominately benthic predators. While the loggerheads foraged on a wide variety of prey items, and even ingested abiotic items, only a few prey items were frequently eaten. Sea pens (Cnidarians, Virgularia presbytes) and nearshore crabs (calico, Hepatus epheliticus; spider, Libinia sp.; and purse, Persephona mediterranea) were the major prey items. She also noted that sea pens anchor in dense stands or beds in sandy sediments. She found sea pens primarily inhabited shallow water and none were found in water deeper than 18 m. V. presbytes is not known to occur in the areas we studied.

Plotkin (1989) reported that both loggerheads and Kemp's ridleys (D. Shaver cited by Plotkin) were preying on crabs, but Kemp's ridleys consumed greater numbers of blue crabs (Callinectes sapidus) and speckled crabs (Arenaeus cribrarius), crab species that were more common in shallow waters. She believed, as we do, that these observations supported the general observations made by Hildebrand (1983). Hildebrand suggested that loggerheads in the northern Gulf were most abundant in waters less than 18 m deep, and Kemp's ridleys occurred most commonly in more shallow waters than loggerheads.

Some locally abundant prey species may attract loggerheads to waters offshore of the Chandeleur and Breton Islands. Stranded loggerheads are, unfortunately, fairly common on the Breton and Chandeleur Islands (Fuller 1988, 1989 and our observations). (For example, on 29 May 1987 we sighted 23 dead sea turtles from the air on the islands. The next day, we went to the islands and studied ten of them, all loggerheads.) A comparative study of the prey items from stranded sea turtles on the Chandeleurs to prey items from stranded loggerheads elsewhere in the Gulf should be undertaken to determine if there is a locally abundant, not ubiquitous, prey that might be attracting loggerheads to the area.

Large loggerheads will also prey on jellyfish (Dodd 1988). During our study, although we observed numerous aggregations of moon jellyfish (Aurelia sp.) and cannonball jellyfish (Stomolophus melagris), we did not observe loggerheads preying on the jellyfish. However, Roden et al. (1990) observed loggerheads preying on jellyfish in some of the areas we studied during surveys in 1987.

What is known about the preferred prey of loggerhead, Kemp's ridley and green sea turtles, and the marine fauna associated with platforms (Gallaway and Lewbel 1982) suggests that platforms would not be especially attractive foraging habitats for adult sea turtles. In addition, we did not find sea turtles to be attracted to the known locations of bottom structures ("hangs"), as might be expected if preferred prey species were also associated with platforms or "hangs." If loggerheads are not attracted to platforms for prey, it seems most likely that when they are found associating with a platform, they are using it for refuge.

Seasonality, Sea Surface Temperatures, and Migrations

Sea turtles are known to migrate, both to nesting beaches (Meylan 1982) and to avoid cold water (Henwood 1987). One way the current mitigation measures for platform removals might be altered would be if sea turtles left the northern Gulf during the winter months. Then explosives could be used to assist the removal of platforms during winter without fear of killing or injuring sea turtles.

Our results indicated that at least some sea turtles remained in the northern Gulf throughout the winter. Sea turtles were present in every shallow water (<200 m) study area except Area 5 during each season including winter. Sea turtles were probably not compelled to leave because of water temperatures. The 1988/89 winter was mild and no major sea surface temperature changes or fronts were found in any of the study areas. Generally, the surface temperatures in Area 5, the most distant offshore and deepest water study area, remained fairly constant, only ranging from about 20-22°C in February to about 25-26°C in August and September. Nearshore surface temperatures were more variable both within months and between months. Areas 3 and 1 were somewhat similar, with surface temperatures ranging from about 15-17°C in February to nearly 30°C in August and September.

Surface temperatures are probably not a good measure of water temperatures from the perspective of a sea turtle. For a marine animal such as a loggerhead, which probably both forages and rests on or near the bottom, bottom water temperatures may be a better measure for correlating loggerhead presence or absence with water temperature. We do not have these data for our study areas. However, overall, long-term interpolated averages of bottom temperatures are available in the Gulf of Mexico Coastal and Ocean Zones Strategic Assessment Data Atlas (1985). These data suggest that bottom water temperatures in our shallow water study areas (Areas 1, 2 and 3) could be expected to be fairly cold in mid-winter, about 16°C. In mid-summer, the bottom water temperature in these areas would be much warmer, probably 27°C or slightly greater. Offshore, in our Area 5, the bottom water temperature probably remains constant, about 20°C, throughout the seasons.

If loggerheads were avoiding seasonally cold water, they could move further offshore or migrate south along the shore, to reach warmer water. However, in Area 1, a shallow water study area, we observed sea turtles every month of the year. In fact, sea turtles were especially common in November 1988 and in February 1989. Twenty-eight percent of all the sea turtles sighted in Area T were sighted in November 1989. Only seven sea turtles were sighted from January through March 1990 in Area T but four were in the most shallow portion of the study area. While these observations do not preclude sea turtles moving to deeper water offshore during the winter months, it is unlikely that loggerheads had enough time to follow a nearshore migratory path to more southern Gulf or Caribbean waters.

One possibility is that loggerheads in the Gulf have a stepwise migration. That is, the sea turtles we observed in Area 1 during the summer actually left early in the fall, and were replaced by loggerheads that had spent the summer somewhere else, perhaps further east in the Gulf. However, this does not seem reasonable because it would mean that some loggerheads were spending the cold months in the northern Gulf while others were not.

We believe it is more likely that loggerheads were employing two strategies to avoid cold water. The slightly increased incidence of sea turtles sighted in Areas 4 and 5 during December and February may indicate that some turtles seek slightly deeper water in the winter. (However, apparently this did not occur in Area T in winter.) Some loggerheads observed in Area 1 in February and March had "mud lines" on their carapaces, like those observed in the Canaveral ship channel in Florida (Carr et al. 1981, Ogren and McVea 1982). We believe it is likely that some loggerheads over-wintered in Area 1, perhaps brumating (Dodd 1988) to avoid cold periods. Byles and Dodd (1989) reported that a large female loggerhead, monitored by a satellite transmitter, offshore of southern Florida, probably brumated for periods of up to 5 days when water temperatures dropped below 18°C.

Sea Turtle Surfacing Behavior

The surfacing behavior of sea turtles is not well known. Without doubt, surfacing behavior of sea turtles is very complicated. It probably varies among species and sizes of sea turtles and perhaps between sexes. It almost certainly varies among seasons, habitats, and probably varies as a result of time of day and other behaviors (e.g., foraging, traveling, resting, etc.). Knowledge of sea turtle surfacing behavior is critical to calibrating the density estimates of sea turtles at the surface to estimates of absolute sea turtle density.

To date, virtually all studies of surfacing behavior have either been observations of captive sea turtles (e.g., Layne 1952) or studies that used radio or satellite telemetry. It is not known to what extent surfacing behavior of captive sea turtles might resemble that of wild sea turtles. A wide variety of both radio and satellite transmitters have been attached to loggerheads, Kemp's ridleys, and to a lesser extent, on leatherbacks. Many different methods of attachment have been used. However, it is unknown if a transmitter package and its method of attachment altered sea turtle behavior and to what extent telemetric data reflect the true surfacing behavior of sea turtles. Nevertheless, results from telemetric studies are the best data available. Research is needed to find the telemetric package and method of attachment for each sea turtle species and size class that least alters their behavior and minimizes the probability of injuring or killing the sea turtle.

Studies of fairly large loggerheads have produced time at surface estimates that range from about 1% to 75% but most estimates were less than 10% (Kajihara et al. 1969, Soma and Ichihara 1977, Kemmerer et al. 1983, Keinath 1986, Nelson et al. 1987, Byles and Dodd 1989). Byles (1989) reported that adult female Kemp's ridleys spent an average of about 4% of their time on the surface. For reasons already discussed in the methods section (sample size, loggerhead sizes and presumed sex ratios, and habitat considerations), we decided to use the estimate that loggerheads spend 8% of the time at the surface (Nelson et al. 1987).

Leatherback Sea Turtles

Leatherbacks have often been described as rare in nearshore waters (Pritchard 1976, 1979, Hendrickson 1980, Rabalais and Rabalais 1980). However, Fritts et al. (1983), Goff and Lien (1988), Knowlton and Weigle (1989), and Leary (1957) have reported nearshore leatherback sightings. We found leatherbacks in our shallow water study areas. Our observations agree with sightings made during our 1986 and 1987 surveys for red drum schools. Leatherbacks were often observed in very shallow water, at times nearly in the surf zone. We have often observed leatherbacks to be associated with aggregations of moon jellyfish or cannonball jellyfish. We have observed leatherbacks preying on cannonball jellyfish by what might be described as "lunging." Knowlton and Weigle (1989) reported that their sightings of leatherbacks in shallow water tended to be sporadic, and that when leatherbacks were sighted, often more than one was observed. In our deep water study areas, we sighted eleven leatherbacks on one day in August

1989 (Area 7) and 14 on one day in October 1989 (Area A). However, during a survey day when at least one leatherback was sighted in a study area, the average number sighted was about 2. Overall, our data from the deep water study areas (Figure 15) indicated that leatherbacks in the northern Gulf of Mexico are most common in water deeper than 200 m.

Leatherbacks in the north-central Gulf were probably responding to a seasonally abundant and spatially discrete prey (jellyfish). Knowlton and Weigle (1989) noted that their leatherback sightings seemed to be most common during the warm months of the year. Over 90% of all our leatherback sightings occurred during the July through November period.

While we believe it is unlikely that leatherbacks would be attracted to platforms, seven of the leatherbacks we observed were within 2,000 m of a platform. Leatherbacks are commonly caught in the longline fishery, where they are attracted to the baited hooks. If organic matter were being regularly discarded from a platform, leatherbacks might be attracted to the platform location. This would increase the probability that this endangered species could be adversely affected by human activities associated with offshore petroleum exploitation.

CONCLUSIONS

East of the Mississippi River, surfaced chelonid sea turtles sighted during daylight hours were positively associated with platforms. Chelonid sea turtles east of the river were 6 to 30 times more abundant than they were west of the river. Because of both the abundance of sea turtles and their positive association with platforms, during the warm months, the probability that one or more sea turtles was within 500 m of any randomly selected platform was about 30% and within 1,000 m, the estimated probability exceeded 50%.

West of the Mississippi River, surfaced chelonid sea turtles were neither significantly positively or negatively associated with petroleum platforms during daylight hours. In spite of the low abundance of sea turtles and their non-association with platforms, the high density of platforms and the consequent short distances between platforms, combined to increase the probability that a sea turtle was relatively near a platform. Probabilities ranged from about 2-7% that one or more sea turtles were within 1,000 m of any randomly selected platform. Because we probably underestimated both the density of sea turtles at the surface and the amount of time a sea turtle spends surfaced, we may have underestimated these probabilities as well as those for east of the river.

East of the river, sea turtles may have been more abundant because of the habitat. Loggerheads nest on the Breton and Chandeleur Islands although factors such as water depth, bottom sediments and prey may be as or more important in explaining their abundance. Whatever the reason, this habitat also happened to be populated by platforms with which sea turtles were associated. Why sea turtles were positively associated with platforms remains unknown. About 18 platforms in Area 1 had greater frequencies of sea turtles within a near distance than expected. Sea turtles, probably loggerheads, may have been attracted to these specific platforms. Based on the MMS data base, these 18 platforms did not appear to differ greatly from other platforms in a similar habitat except that more of the 18 platforms were unmanned and they were generally smaller.

Chelonid sea turtles were present offshore of Louisiana throughout the year. The reduced numbers observed during the winter months may simply have been a result of sea turtles spending less time on the surface, not an actual reduction in abundance of sea turtles. Some loggerheads observed in Area 1 in February and March 1989 had characteristic "mud lines" on their carapaces, strongly suggesting that they had been buried in the bottom sediments for some time.

Leatherbacks were more common in deep water (>200 m) in our study. However, leatherbacks, an endangered species, may occur in relatively shallow water during any month of the year. This fact must be considered when planning any marine activities that might harm leatherbacks.

Future research in the following areas would help to better understand the abundance and distribution of sea turtles east of the Mississippi River and to better assess the risk of platform removals to all sea turtles:

1. Surfaced chelonid sea turtles were most common over sandy bottom sediments in Area 1. However, access to a bottom sediment data base with better resolution than the NMFS data base is needed to determine if this association is valid.

2. A comparative study of prey items found in loggerheads stranded on the Chandeleur Islands to those found in loggerheads stranded elsewhere in the Gulf is needed to determine if a locally abundant prey source is attracting loggerheads to the area offshore of Breton and Chandeleur Islands.

3. How many loggerheads nest on the islands is unknown. More research is needed to determine if these unique Gulf of Mexico islands, serving as a nesting beach, solely explains why loggerheads are so abundant offshore of the islands.

4. A major type of data needed is an accurate and relatively precise estimate of the percent time a sea turtle is surfaced. This estimate is essential for estimating absolute abundance and the probability of risks to sea turtles. However, because sea turtle surfacing behavior is probably influenced by many factors (habitats, seasons, species, sex, and size class), these studies should be conducted in the same area where sea turtle abundance is being estimated. Also, it is critical that the method of determining the percent time a sea turtle spends surfaced does not affect the normal surfacing behavior of sea turtles.

In conclusion, we believe the current mitigation measures should be adequate to protect sea turtles from the potentially harmful effects of using explosives to assist platform removal from the mouth of the Mississippi River west to about 92°W longitude. However, from the mouth of the Mississippi River east to about 88°W longitude, there is a very high probability of one or more sea turtles being fairly close to a platform. In this area, additional measures, such as more observers or a longer observation time, might be required to ensure protection of sea turtles when explosives are used to assist platform removal. Serious consideration should be given to using other methods of platform removal in this area.

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APPENDIX 1

Data Base Description

1. DATA RECORDS

Each data record is 72 characters long. Blank fields complete the data record for records that contain less than 72 characters. Each data file has been named for the day , month, year, and "part number" for the date of the survey. The part number was used when the survey day was broken into 2 portions (because of refueling, etc.). A 3 character suffix (SUR) was added each file name to describe the data file as a raw survey data file. Example of survey data file names are "010189P1.SUR" or "120788P2.SUR." The following data types (variables) were used in the June 1988 through November 1989 surveys for marine animals, human activities, and pollution.

VARIABLE NAME	FIELD WIDTH	RECORD PLACEMENT	DATES AND NOTES
CARD	1	1	06/88 - 11/89
AREA	3	2-4	"
PART	2	5-6	"
DAY	2	7-8	"
MONTH	2	9-10	"
YEAR	2	11-12	"
HOUR	2	13-14	"
MINUTE	2	15-16	"
SECOND	2	17-18	"
LATITUDE	6	19-24	"
LONGITUDE	6	25-30	"
TRACK	3	31-33	"
SPEED	3	34-36	"
WARN	1	37	"
ALTITUDE	4	38-41	"
WEATHER	1	42	"
SEA STATE	1	43	"
TURBIDITY	1	44	"
SUNLIGHT	1	45	"
GLARE	1	46	"
WATER COLOR	1	47	"
WATER TEMPERATURE	2	48-49	"
SPECIES 1	2	50-51	"
SPECIES 2	2	52-53	"
SPECIES 3	2	54-55	"
SPECIES 4	2	56-57	"

Data Base Description, Continued

VARIABLE NAME	FIELD WIDTH	RECORD PLACEMENT	DATES AND NOTES
OBSERVER	1	58	06/88 - 11/89
OBSERVATION ANGLE	2	59-60	"
HERD/SCHOOL SIZE	1	61	"
TURTLE BEHAVIOR	1	62	"
PLATFORM DISTANCE	2	63-64	06/88 - 05/89
PLATFORM TYPE	1	65	"
HUMAN ACTIVITY	1	66	06/88 - 05/89
PHOTOGRAPHS TAKEN	1	67 OR 63 [(67)	TO 05/89 THEN (63)]
WHALE COUNT	3	64-66	07/89 - 11/89
WHALE CALF COUNT	2	67-68	"

2. CARD TYPES

The first character of each data record is a card type. The card type defines what type of data record follows. Card types were:

A = BEGIN STUDY AREA
B = BEGIN TRANSECT
C = ENVIRONMENTAL CHANGE
D = SIGHTING
E = GOING OFF TRANSECT
F = no F records in the data base
G = BACK ON TRANSECT
H = END TRANSECT
I = END STUDY AREA
J = no J records in the data base
S = SPACE/TIME CHECK (We designed this record to document the aircraft's location at a specified time interval. We usually used 1 minute as the time interval and S cards would be recorded if no other record had been recorded in the preceding minute.)

3. DATA BASE COMPOSITION

The data contained in type of data record is indicated by an "X."

DATA TYPE	A	B	C	D	E	G	H	I	S
	RECORD TYPE								
AREA	X	X	X	X	X	X	X	X	X
PART	X	X	X	X	X	X	X	X	X
DAY	X	X	X	X	X	X	X	X	X
MONTH	X	X	X	X	X	X	X	X	X
YEAR	X	X	X	X	X	X	X	X	X
HOUR	X	X	X	X	X	X	X	X	X
MINUTE	X	X	X	X	X	X	X	X	X
SECOND	X	X	X	X	X	X	X	X	X
LATITUDE	X	X	X	X	X	X	X	X	X
LONGITUDE	X	X	X	X	X	X	X	X	X
TRACK	X	X	X	X	X	X	X	X	X
SPEED	X	X	X	X	X	X	X	X	X
WARN	X	X	X	X	X	X	X	X	X
ALTITUDE	X	X	X	X	X	X	X	X	X
WEATHER		X	X	X			X		X
SEA STATE		X	X	X			X		X
TURBIDITY		X	X	X			X		X
SUNLIGHT		X	X	X			X		X
GLARE		X	X	X			X		X
WATER COLOR		X	X	X			X		X
WATER TEMPERATURE		X	X	X			X		X
SPECIES 1				X					
SPECIES 2				X					
SPECIES 3				X					
SPECIES 4				X					
OBSERVER				X					
OBSERVATION ANGLE				X					
HERD/SCHOOL SIZE				X					
TURTLE BEHAVIOR				X					
PLATFORM DISTANCE				X					
PLATFORM TYPE				X					
HUMAN ACTIVITY				X					
PHOTOGRAPHS TAKEN				X					
NUMBER OF CETACEANS				X					
NUMBER OF CALF CETACEANS				X					

4. VARIABLE DESCRIPTIONS

AREA

A 3 character code where "SA" stands for Study Area and the third character is either 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, or A, which represent the study area being studied. A stood for DeSoto Canyon and 0 indicated a beach survey for stranded animals and turtle nests.

PART

A 2 character code where "P" stood for Part and the numeral indicated what segment (1,2,3,....9) of the day's surveys were included in the file.

DAY, MONTH, YEAR

A computer supplied variable, written without divisions between the parts (e.g., 021288 = December 2, 1988).

HOUR, MINUTE, SECOND

Again a computer supplied variable and written without divisions between the parts.

LATITUDE and LONGITUDE

Supplied by the LORAN-C receiver interfaced to the computer, each consists of degrees, minutes, and hundredths of a minute.

TRACK

Supplied by the LORAN-C receiver interfaced to the computer, the compass direction in degrees of the current heading of the aircraft.

SPEED

Supplied by the LORAN-C receiver interfaced to the computer, the ground speed was recorded from 0 to 999 NM/h.

WARN

Indirectly supplied by the LORAN-C receiver interfaced to the computer, if any of the 3 LORAN-C signal Signal to Noise Ratios were less than 64, then a flag was placed in the data recorded indicating the aircraft's location, track and speed might be suspect. The flag was:

0 = all SNRs above 64,
1 = Warning, 1 or more SNRs less than 64

ALTITUDE

Altitude was recorded as feet above sea level (0 to 9999 ft) and was supplied by the aircraft's instruments.

WEATHER

An observer supplied subjective rating where:

1 = CLEAR (0-10% CLOUD COVER)
2 = PARTLY CLOUDY (10-50% CLOUD COVER)
3 = CLOUDY (50-100% CLOUD COVER)
4 = LIGHT RAIN
5 = CLEAR BUT HAZY
6 = PARTLY CLOUDY AND HAZY
7 = CLOUDY AND HAZY
8 = FOG OR LOW CLOUDS

SEA STATE

An observer supplied subjective rating where:

0 = NO WHITECAPS
1 = SMALL WAVES, FEW WHITECAPS
2 = 0-33% WHITECAPS, WAVES 1-2 FEET
3 = 33%-50% WHITECAPS, WAVES 2-3 FEET
4 = > 50% WHITECAPS, WAVES > 3 FEET
5 = WORSE CONDITIONS THAN 4

WATER TURBIDITY

An observer supplied subjective rating where:

0 = GOOD
1 = FAIR
2 = POOR

SUNLIGHT QUALITY

An observer supplied subjective rating where:

0 = NONE
1 = POOR
2 = FAIR
3 = MODERATE
4 = GOOD
5 = EXCELLENT

GLARE

An observer supplied subjective rating where:

0 = NO HINDRANCE
1 = HINDRANCE ON ONE SIDE
2 = HINDRANCE ON BOTH SIDES

WATER COLOR

An observer supplied subjective rating where:

1 = BROWN
2 = GREEN
3 = GRAY
4 = BLUE
5 = BLUE/GREEN
6 = BROWN/GRAY
7 = GREEN/GRAY
8 = GREEN/BROWN
9 = DARK GREEN

WATER TEMPERATURE

The surface temperature of the water was measured by a remote sensor and a Precision Radiation Thermometer (Model 5) receiver. Because the data was of questionable precision and accuracy, and because the remote sensing satellite data proved to be more useful, we discontinued collecting surface water temperature by this method in September, 1988.

SIGHTING CODES (SPECIES 1, 2, 3, AND 4)

Up to 4 individuals of a species or up to 4 species could have been recorded per sighting. Other codes (95 through 98) allowed us to record more numerous sightings - up to 151 per sighting record. Numeric codes representing marine animals, human activities, and pollution were:

1 Loggerhead Sea Turtle
2 Leatherback Sea Turtle
3 Unidentified Sea Turtle but not a Loggerhead or Leatherback
4 Green, Kemp's Ridley, or Hawksbill Sea Turtle (described in the audio log)
5 Unidentified Sea Turtle but not a Leatherback
6 Manatee
7 Bottlenose Dolphin
8 Stenella sp.
9 Unidentified small cetacean(s)
10 Unidentified large cetacean(s)
12 Spotted Dolphin
13 Striped Dolphin
14 Spinner Dolphin
15 Common Dolphin
16 Pygmy Killer Whale
17 Pygmy or Dwarf Sperm Whale
18 Risso's Dolphin
19 Pilot Whale
20 Human Activity
21 False Killer Whale
22 Beaked Whale
23 Killer Whale
24 Minke Whale
25 Bonito
26 Tuna
27 King Mackerel
28 Crevalle Jack
29 Unknown Ray School
30 Dolphin Fish
31 Tarpon
32 Red Drum
33 Black Drum
34 Cobia
35 Sunfish
36 Manta Ray
37 Cownose Rays
38 Unknown Ray (1 or 2)
39 Hammerhead Shark
40 Unknown, not Hammerhead, Shark
41 Whale Shark
42 Shark School

SIGHTING CODES (SPECIES 1, 2, 3, AND 4), Continued

43 Southern Bottlenose Whale
44 Sperm Whale
45 Humpback Whale
46 Bryde's Whale
47 Right Whale
48 Sei Whale
49 Fin Whale
50 Unknown Large Fish
51 Blue Runners
52 Spadefish
53 Thread Herring
54 Spanish Mackerel
55 Menhaden
56 Mullet
57 Anchovies
58 Atlantic Bumpers
59 Catfish
60 Bluefish
61 Ground Mullet
62 Flying Fish
63 Either Drum or Jacks
64 Cannonball Jellyfish
65 Other Jellyfish
70 Unknown Small Fish
75 Blue Whale
80 Anchored Shrimp Trawler
81 Trawling Shrimp Trawler
82 Longline Boat
83 Purse Seiner
84 Charter Fishing Boat
85 Recreational Fishing Boat
86 Fish Trawler
87 Seismographic Boat
88 Platform Service Boat
89 Other Boat (noted in audio log)
90 Plastic Rope
91 Longline Fishing Gear
92 Plastic
93 Oil Slick
94 Other Pollution (noted in audio log)
95 10 - 20 schools or sightings
96 21 - 30 schools or sightings
97 31 - 40 schools or sightings
98 41 - 50 schools or sightings

OBSERVER

Which observer made the sighting, where:

1 = LEFT
2 = RIGHT

OBSERVATION ANGLE

For sea turtle sightings the observation angle was the digital inclinometer reading to the nearest degree. For other sightings the angle was one of 7 intervals, where each interval represent 10°from vertical (i.e., 1 = 0 to 10 degrees, 2 = 11 to 20 degrees, etc.). In addition, 0 was used to record a missing interval or angle. Except for sea turtles, no sightings were recorded when the sighting interval was greater than 7.

SIZE

When used to record number of cetaceans, the codes were:

1	1 to 5 cetaceans
2	6 to 12 cetaceans
3	13 to 20 cetaceans
4	20 to 50 cetaceans
5	> 50 cetaceans

When used to record the size of drum schools, the codes were:

1	< 5,000 lbs
2	5,000 - 20,000 lbs
3	20,000 - 60,000 lbs
4	60,000 - 100,000 lbs
5	> 100,000 lbs

BEHAVIOR

For sea turtle sightings, the behavior codes were:

1 - SWIMMING
2 - BASKING
3 - NEAR SURFACED
4 - COPULATING OR INTERSPECIFIC ACTIVITY
5 - DIVING
6 - OTHER BEHAVIOR (noted in the audio log)

BEHAVIOR, Continued

For cetacean sightings, the behavior codes were:

1 - TRAVELING
2 - RESTING
3 - FORAGING
4 - COMPLEX SOCIAL ACTIVITY
5 - MILLING
6 - UNKNOWN (noted in the audio log)

PLATFORM DISTANCES

This variable field was discontinued from the data records in July, 1989 and was only recorded from June, 1988 through August, 1988, when a sea turtle was sighted the observer noted the interval (1 through 7) of the nearest platform. However, this did not prove practical. It required too much of the observer's attention from the turtle sighting, and it did not take into account platforms on the other side of the trackline from the sighting.

PLATFORM TYPES

This variable field was discontinued from the data records in July, 1989 and was only recorded from June, 1988 through August, 1988, when a sea turtle was sighted the observer noted the type of platform nearest to the turtle, where the codes were:

1 = SINGLE CAISSON
2 = SMALL PLATFORM (4 OR LESS LEGS)
3 = MEDIUM PLATFORM (6 - 10 LEGS)
4 = LARGE PLATFORM (12 OR MORE LEGS)
5 = WOODEN PLATFORM
6 = PLATFORM COMPLEX OF SIMILAR SIZED PLATFORMS
7 = PLATFORM COMPLEX OF DIFFERENT SIZED PLATFORMS
8 = DRILLING PLATFORMS
9 = BUOY

However, this did not prove practical. It required too much of the observer's attention from the turtle sighting, and it did not take into account platforms on the other side of the trackline from the sighting. Also, judging which platform was nearest the sighting was difficult.

HUMAN ACTIVITY

This variable field was discontinued from the data records in July, 1989 and was only recorded from June, 1988 through August, 1988, this code was used to record whether human activity was noted on the nearest platform to the sea turtle sighting. For reasons already noted, recording these data was not practical. When recorded, the code was:

0 - NO HUMAN ACTIVITY NOTED
1 - HUMAN ACTIVITY NOTED

PHOTOGRAPHS TAKEN?

Used to record if special or unusual photographic records were recorded for a sighting, the code was:

0 - NO
1 - YES

NUMBER OF CETACEANS

This variable field was added to the data records in July, 1989 and was used to largely replace the cetacean herd size classes (although these were still automatically recorded for the July through November, 1989 data). The number includes both adults and calf cetaceans of a species or type per sighting. To derive only number of large or adult cetaceans, subtract numbers of calves from this variable.

NUMBER OF CETACEAN CALVES

This variable field was added to the data records in July, 1989. The number of calves was also included in the number of cetaceans variable.

APPENDIX 2

SEA TURTLE SIGHTINGS

1. Areas 1-6

Number of sea turtles sighted per study month per study area. Sea Turtle Codes: 1 = Loggerhead, 2 = Leatherback, 3 = Unidentified Chelonid Sea Turtle but not a Loggerhead, 4 = Green, Kemp's Ridley, or Hawksbill Sea Turtle, and 5 = Unidentified Chelonid Sea Turtle.

Study Area Turtle Type	1988							1989								
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Area 1																
1	10	6	4	4	17	11	2	1	8	5	10	33	-	14	8	12
2	0	0	0	0	0	2	0	0	0	0	1	0	-	1	2	1
3/4	3	0	0	0	0	1	0	0	2	1	1	0	-	0	1	0
5	5	3	1	3	6	1	0	2	0	1	6	6	-	6	0	0
Area 2																
1	2	1	1	1	3	2	0	0	0	0	1	2				
2	0	4	2	0	0	1	1	0	0	0	0	0				
3/4	1	0	0	0	0	0	0	1	0	0	0	0				
5	0	2	2	2	1	1	0	0	0	1	0	2				
Area 3																
1	4	0	0	0	1	0	1	0	0	0	0	0				
2	0	0	0	0	0	0	0	0	0	0	0	0				
3/4	2	0	0	0	2	0	0	0	0	0	0	0				
5	3	0	0	2	0	0	0	0	0	0	0	0				
Area 4																
1	3	1	0	0	0	0	3	0	0	3	2	1				
2	1	0	1	0	0	0	1	0	0	0	0	0				
3/4	4	0	0	0	0	0	0	0	1	0	0	0				
5	1	0	1	0	0	1	1	0	0	1	0	0				

continued

Areas 1-6, continued

Study Area Turtle Type	1988 J	J	A	S	O	N	D	1989 J	F	M	A	M	J	J	A	S
Area 5																
1	0	1	0	0	0	0	1	0	1	0	0	0				
2	0	0	0	0	0	0	0	0	0	1	0	0				
3/4	1	0	0	0	0	0	0	0	0	0	0	0				
5	1	0	0	0	0	0	0	0	0	0	0	0				
Area 6																
1														0	0	0
2														2	0	0
3/4														0	0	0
5														0	0	0

2. Area T

Number of sea turtles sighted per study month per study area. Sea Turtle Codes: 1 = Loggerhead, 2 = Leatherback, 3 = Unidentified Chelonid Sea Turtle but not a Loggerhead, 4 = Green, Kemp's Ridley, or Hawksbill Sea Turtle, and 5 = Unidentified Chelonid Sea Turtle.

Study Area Turtle Type	1989 O	N	D	1990 J	F	M	A	M	J
Area T									
1	8	14	-	0	0	3	10	9	5
2	0	4	-	0	0	0	0	0	0
3/4	0	0	-	0	0	0	0	0	0
5	0	1	-	3	0	1	1	0	0

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 the wisest use of our land and water resources, protecting our fish and wildlife, 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 assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.