Impacts of the Explosive Removal of Offshore Petroleum Platforms on Sea Turtles and Dolphins

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ABSTRACT—Strandings of 51 dead sea turtles (primarily Kemp's ridley, Lepidochelys kempi*), 40 dolphins (primarily bottlenose dolphin,* Tursiops truncatus*) and many fish were recorded on beaches in the northwestern Gulf of Mexico from 19 March to 19 April 1986. During this period explosives were used to remove several oil platforms in adjacent offshore waters. Drift bottles released at the site of one of the explosions were recovered with some of the strandings. Shrimp fishing activity, a known cause of turtle mortality, was at a normal seasonal low. Circumstantial evidence suggests that at least some of the strandings of marine animals may have been due to underwater explosions used in removal of oil platforms.*

A total of 11 turtles were observed at 7 of 52 removal sites from 5 April 1986 through 5 August 1988, and a maximum of 100 dolphins were observed at each of 38 sites. One wild sea turtle was observed sinking after an explosion, but it could not be recovered to document its injuries. Necropsy of one stranded loggerhead turtle, Caretta caretta, *found two days after a 1987 removal showed hemorrhaging of the lungs which is consistent with impacts of an explosion; this condition may also be attributed to postmortem decomposition of tissue. In a preliminary experiment, two of four Kemp's ridley and three of four loggerhead turtles were rendered unconscious after placement within 915 m of the simultaneous explosion of four 23 kg charges.*

Comparison of turtle strandings during periods characterized by high and low numbers of offshore explosions, March-April 1985-88, suggested a positive relationship between the frequency of explosions and the stranding of turtles. Although dolphins may be impacted by explosions, the relationship between the stranding of dolphins and offshore explosions was not as conspicuous.

Introduction

Between 19 March and 19 April 1986, 51 dead sea turtles, primarily the endangered Kemp's ridley, *Lepidochelys kempi*, were found on beaches of the upper Texas coast. Ten petroleum structures were removed from this area when shrimping activity, a factor contributing to turtle mortality, was at a seasonal low (Fig. 1).

During the summer of 1986 the Interior Department's Minerals Management Service (MMS) and the Commerce Department's National Marine Fisheries Service (NMFS) discussed the effects of offshore explosions on endangered and threatened sea turtles. They agreed to hold formal consultations, as provided under Section 7 of the Endangered Species Act of 1973, for each proposed use of explosives in Outer Continental Shelf (OCS) waters of the Gulf of Mexico. Beginning in 1987, companies planning to remove oil and gas structures (platforms, caissons, well conductors, flare stacks, etc.) with explosives were required to obtain a permit from MMS. Permits authorized the use of explosives provided the company followed certain requirements which generally included: 1) Visual monitoring for turtles around the removal site by observers, approved by NMFS, operating from the work platform and frequently from helicopters, 2) pre- and post-blast diver surveys for sea turtles, 3) delaying detonations to allow observed turtles to leave the area, 4) detonating only during daylight hours to facilitate visual monitoring, and 5) staggering detonations to reduce the maximum pressure generated by the explosions.

High-velocity explosives are typically used to sever pilings and conductors 5 m below the mudline during removal operations. A crane then lifts these structures out of the water to a barge for return to shore. It is important to assess the potential impacts of these activities on sea turtles and other marine life. MMS estimates that there were 3,435 platforms in the Federal OCS as of December 1986, and predicts between 60 and 120 structures will be removed annually for the next 5 years. The National Research Council (NRCMB, 1985) estimates that about 1,700 structures will be scheduled for removal between 1984 and 2000. The Council predicts about 100-130 removals annually between 1990 and 2000.

This paper reports on 1) the relationship of explosive events with strandings of sea turtles and dolphins, 2) biological monitoring at 52 structure removal sites during 5 April 1986 through 5 August 1988, and 3) an experiment in which sea turtles were exposed to underwater explosions associated with the removal of a platform. Information pertaining to the association of turtles with offshore structures and the impacts of underwater explosions on turtles and dolphins is also discussed.

Materials and Methods

Sea Turtle Stranding Network

Since 1980, a sea turtle stranding network, operating primarily on a volunteer basis, has collected data from the U.S. Gulf of Mexico and Atlantic coasts.

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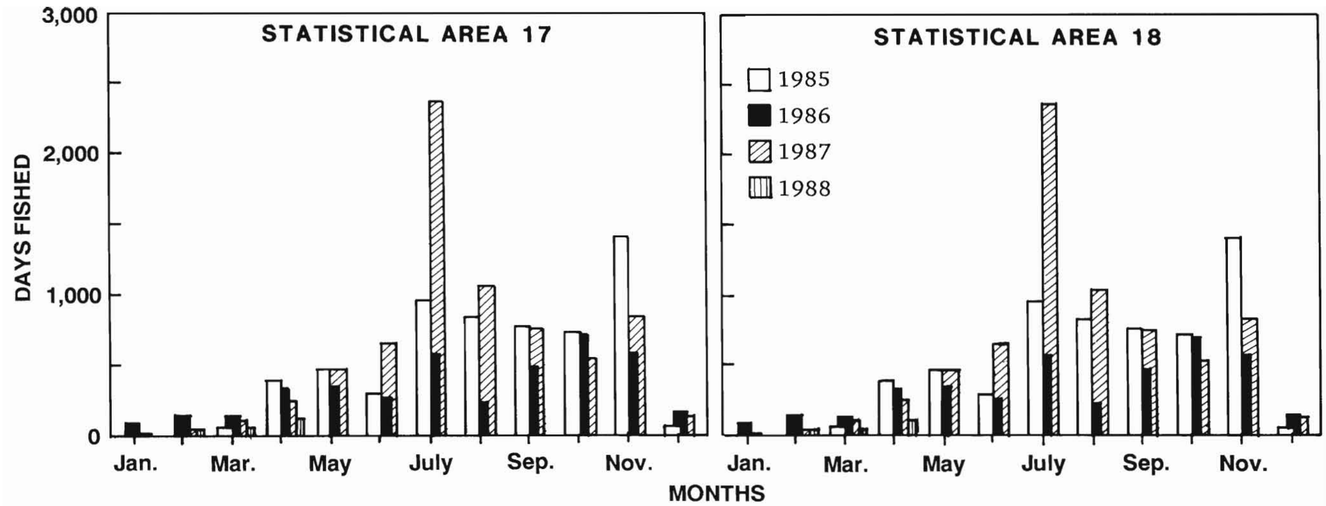

Figure 1.—Offshore shrimping effort in 0-18 m depths for Statistical Areas 17 and 18, 1985-88.

All information is centralized at the NMFS Miami Laboratory. The NMFS Sea Turtle Stranding and Salvage Network (STSSN) has been documenting beach strandings of turtles along the Texas and western Louisiana coasts through routinely scheduled surveys since the spring of 1986. Prior to this, NMFS surveyed the beach only in response to strandings reported by the public. Organizations supporting this network include the University of Texas Marine Science Center, McNeese State University, Louisiana Department of Wildlife and Fisheries, and the U.S. Fish and Wildlife Service.

Both the area and frequency of coverage have increased tremendously since inception of the program. Nearly all U.S. beaches along the Gulf of Mexico west of the Mermentau River, Louisiana, are surveyed biweekly if accessible by pickup truck, motorcycle, or all-terrain vehicle. Some estuarine and remote island shorelines have been included in the survey area. To assess the effects of explosions more accurately, surveys along the coastline were generally intensified near inshore platform removal sites both immediately prior to and following scheduled structure removal (Fig. 2).

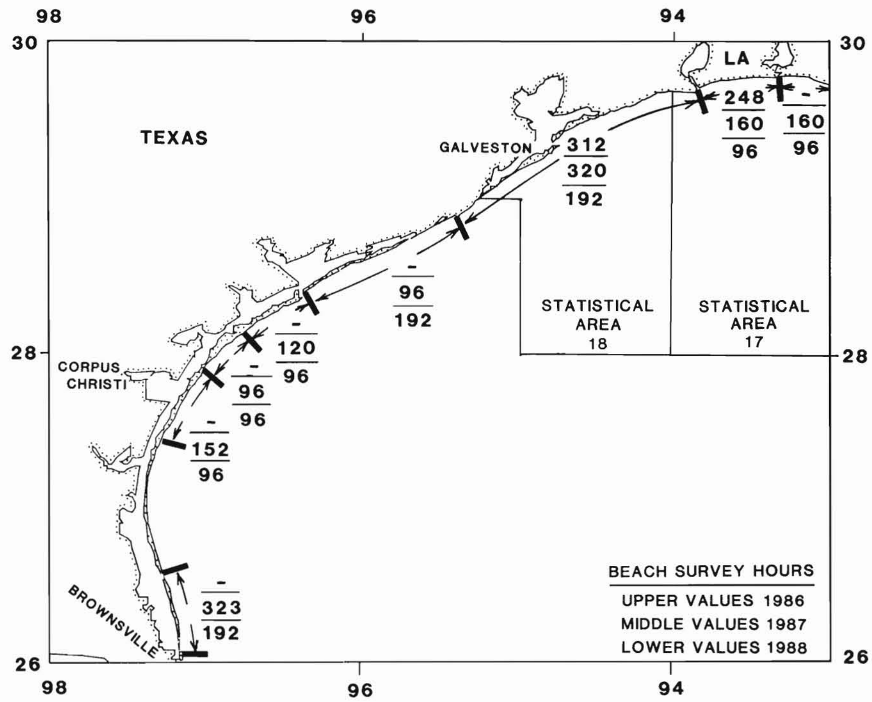

Figure 2.—NMFS-sponsored beach survey effort (man-hours) for monitoring turtle stranding events along the western coast of the Gulf of Mexico. Upper numerals represent 1986 hours, middle numerals 1987 hours and lower numerals 1988 (through June) hours expended on surveys of the coastline as indicated.

Marine Mammal Stranding Network

The National Marine Mammal Stranding Network operates primarily on a volunteer basis and responds to calls from the public. Organizers in various states report strandings to a central office in Orlando, Fla. Data in this paper were supplied by the Texas Marine Mammal Stranding Network, College of Veterinary Medicine, Texas A&M University. Information gathered through the NMFS Sea Turtle Stranding Network has assisted in the acquisition of data on marine mammal strandings.

NMFS Monitoring of Platform and Caisson Removals

Observers monitored the area around structure removal sites prior to, during, and after detonation of explosives (Fig. 3, Table 1). Pre-blast monitoring for sea turtles was conducted from 1) the work and/or materials barges, 2) the structure being removed, 3) tug boats or crew boats as available, and 4) helicopters, if required in the Section 7 consultation authorized by the Endangered Species Act. Observers used helicopters to survey around the removal site to a distance of 1.5 km. Thirty minute flights were made within 1 hour prior to, and immediately following, the detonations. Detonations were delayed 1 hour if sea turtles or marine mammals were observed within 915 m of the detonation site, and the survey was repeated, unless there was verification that the animals had moved beyond the 915 m range. Oil company divers made pre-blast dives around the structures to document the presence of sea turtles, marine mammals, and fish.

In all but one case, explosives were detonated no earlier than 1 hour after sunrise nor later than 1 hour before sunset. Following the detonations, dead or injured marine life were sampled on the bottom by divers and on the surface by personnel operating from a vessel. Observers in helicopters assisted this effort by communicating their observations to personnel collecting the animals. Fish were measured and identified. Drift cards were released at the removal sites in an attempt to document surface currents, and to assist in correlating the location of strandings with offshore explosions.

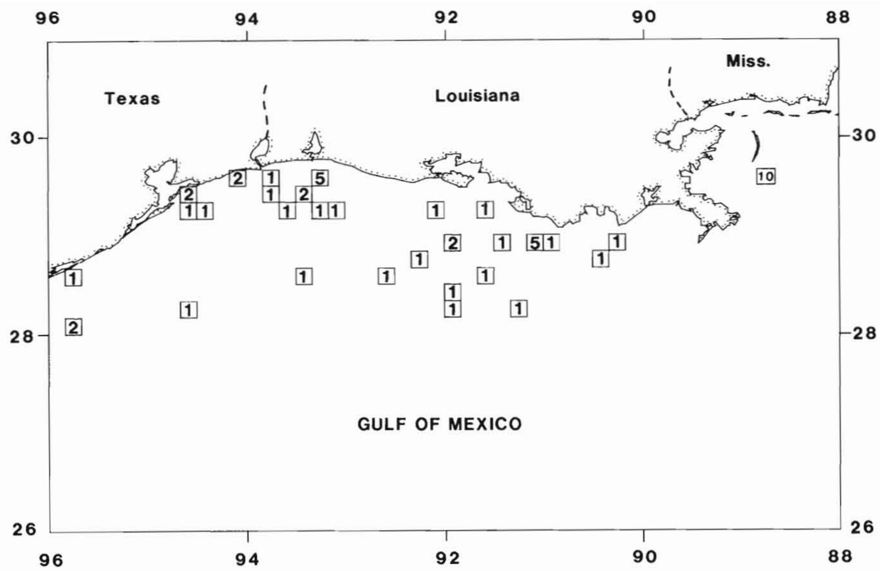

Figure 3.—Locations of NMFS monitored platform and caisson removals. The number of structures removed is indicated by numerals in the squares; 10 n.mi. on a side.

Exposure of Turtles to an Underwater Explosion

An experiment was designed to provide preliminary information on the extent of the impact zone created by the explosive removal of an offshore platform. Kemp's ridleys weighing 0.6, 1.3, 1.5, and 6.7 kg and loggerhead turtles, *Caretta caretta*, weighing 4.0, 4.2, 5.5, and 6.8 kg were placed in plastic mesh, steel-framed cages (0.9 m × 0.9 m × 1.2 m), one turtle of each species at four distances (229 m, 366 m, 549 m, and 915 m). Turtles were unrestrained and allowed to swim freely in the cages. All turtles had deformed flippers but were otherwise healthy, and all were permanent residents of the NMFS Southeast Fisheries Center's Galveston Laboratory. The cages were submerged to a depth of 4.5 m over the 9 m sea bottom just prior to the simultaneous explosion of four 23 kg charges of nitromethane placed inside the platform pilings at a depth of 5 m below the mudline. The energy level of the shock wave generated by the explosion was estimated by Cummings[1] for each of the four distances. Immediately following the explosion, turtles were retrieved and inspected carefully for external damage. Seabed drifters and drift bottles were released to define prevailing currents that might carry injured or dead marine animals ashore. All animals were transferred to the NMFS Galveston Laboratory and examined daily for the next month. The experiments were undertaken with the permission of the U.S. Fish and Wildlife Service under Permit No. PRT-676379.

[1]William Cummings, TRACOR, 9150 Chesapeake, Suite 107, San Diego, CA 92123. Unpubl. data.

Shrimp Fleet Fishing Effort

Detailed catch statistics for the U.S. Gulf of Mexico shrimp fishery have been compiled since 1956, and the procedures used to collect them are described by Klima (1980).

Results

Relationship of Explosive Events With Strandings of Marine Life

A series of at least 22 explosions occurred between 19 March and 5 April 1986 in conjunction with oil field structure removals within 7-11 km of the Bolivar Peninsula, near Galveston, Tex. (Table 2). During this period and the following 2 weeks 51 dead turtles were found on beaches in Statistical Area 18 which includes Bolivar Peninsula and Galveston Island (Fig. 4). Of the 51 turtles stranded, 25 (49 percent) were reported within an 11 km radius and 44 (86 percent) within a 54 km radius of the structures that were removed. Forty-

Table 1.—Man-hours of observation at NMFS monitored removals with accompanying sightings of turtles and dolphins. Refer to Figure 3 for platform locations.

Date of removal	Approx. distance from shore (n.mi.)	Depth (m)	Structure removed	Man-hours of observation (day/night)	Turtles sighted	Dolphins sighted
4/86	1	9	Platform	8/0	0	26
7/86	75	42	Platform	76/48	4	18
11/86	10	15	Platform	28/14	0	0
12/86	6	12	Caisson	11/0	0	7
12/86	9	12	Caisson	10/0	0	8
3/87	55	39	Platform	52/45	2	24
4/87	21	16	Caisson	13/0	1	13
6/87	17	27	Platform	73/0	0	26
9/87	15	10	Caisson	9/0	0	9
9/87	18	15	Caisson	7/9	0	1
9/87	18	15	Caisson	14/3	0	30
10/87	80	72	Platform	99/20	0	0
11/87	35	20	Platform	53/8	0	2
11/87	60	56	Platform	146/37	0	27
1/88	32	12	Platform	80/33	0	0
1/88	32	9	Platform	26/2	0	0
2/88	25	17	Platform	56/14	1	30
2/88	10	8	Platform	32/8	0	10
2/88	40	33	Platform	32/15	0	16
2/88	51	71	Platform	35/9	0	100
2/88	13	12	Caisson	10/2	0	1
2/88	12	11	Caisson	30/0	0	2
2/88	13	11	Caisson	8/2	0	3
3/88	14	12	Caisson	10/0	0	0
3/88	13	12	Caisson	10/0	0	1
3/88	55	17	Platform	32/9	0	0
4/88	64	49	Platform	82/48	0	51
4/88	62	58	Platform	37/5	0	0
4/88	28	43	Platform	108/31	0	28
4/88	28	43	Platform	12/4	0	1
5/88	30	21	Caisson	42/25	0	4
5/88	30	21	Caisson	43/25	0	3
5/88	13	4	Caisson	11/4	0	15
5/88	21	8	Caisson	7/1.5	0	0
5/88	21	8	Caisson	3/0	0	0
5/88	21	7	Caisson	4.5/0	0	0
5/88	21	7	Caisson	2.5/0	0	0
5/88	21	6	Caisson	3/0	0	0
5/88	9	11	Platform	25/4	0	0
6/88	9	19	Caisson	73/63	0	20
6/88	65	20	Caisson	9/5	0	0
6/88	66	19	Caisson	11/5	0	1
6/88	66	22	Caisson	19.5/2.5	0	10
6/88	63	18	Caisson	8/5	0	12
6/88	62	19	Caisson	11/2	1	10
6/88	62	17	Caisson	7/5	0	1
6/88	63	19	Caisson	8/1	0	20
6/88	64	19	Caisson	5/0	0	3
6/88	64	19	Platform	1.5/1.5	0	1
7/88	21	8	Platform	56/29.5	0	27
8/88	8	20	Platform	22.5/11	1	3
8/88	13	21	Platform	44/0	1	0

Table 2.—March-April 1986 schedule of removals of oil and gas field structures off Bolivar Peninsula. The total weight (kg) of explosives utilized at each detonation and the number of turtles and dolphins stranded in Statistical Area 18 during this time period are also presented.

Date	Weight of explosives (kg)	24 hr time	Approximate Lat.	Long.	Turtles	Dolphins
1-18 March					9	4
19	45	1632	29° 25′	94° 39′	0	3
	109	1758	29° 25′	94° 39′		
20	27	2235	29° 25′	94° 39′	1	0
21	109	1703	29° 25′	94° 39′	3	0
22	27	1130	29° 25′	94° 39′	0	0
23	27	0815	29° 25′	94° 39′	0	1
24	109	1425	29° 25′	94° 39′	0	0
25	45	1100	29° 25′	94° 39′	0	0
	76	1333	29° 25′	94° 39′		
26	18	1630	29° 25′	94° 39′	5	2
27	109	1220	29° 28′	94° 30′	1	0
	27	1440	29° 25′	94° 39′		
28	27	1545	29° 25′	94° 39′	3	0
29	27	0845	29° 25′	94° 39′	0	0
	109	1310	29° 25′	94° 39′		
	55	2330	29° 25′	94° 39′		
30	35	1020	29° 25′	94° 39′	3	14
31	109	1015	29° 25′	94° 39′	1	0
1 April	23	1710	29° 25′	94° 39′	2	4
2	76	0805	29° 25′	94° 39′	0	0
3					0	0
4					1	4
5	59	1251	29° 25′	94° 39′	2	1
	109	1451	29° 25′	94° 39′		
6-19					29	12
20-30					32	5

one bottlenose dolphins, *Tursiops truncatus*, 15 of which were apparently smaller than the usual size at birth (i.e., fetuses ≤120 cm total length), also stranded (Fig. 4). After two detonations (168 kg of explosive) on April 5, sheepshead, *Archosargus probatocephalus*; black drum, *Pogonias cromis*, and a variety of other fish species were observed floating on the surface. Perforated air bladders were found in five sheepshead collected in bottom trawls after the detonations (Landry[2]). Fifty-four sheepshead and 69 black drum were stranded along 22 km of beach immediately inshore of the removal site over the next 14 days (Fig. 5, 6).

Turtles

Beaches in Statistical Area 18 were surveyed for about 312, 320, and 192 man-hours in 1986, 1987, and through June 1988, respectively. In 1985, however, NMFS personnel examined the beaches in this area only in response to public reports of stranded marine life.

From 19 March to 19 April, nine turtle strandings were reported in Statistical Area 18 during 1985, 51 in 1986, 4 in 187, and 5 in 1988. Based on the state of decomposition of a turtle and the reported date of stranding, one turtle from each of the 1985 and 1986 data sets had died previous to the March-April sampling period.

At least 22 explosions were reported in Texas State waters of Area 18 during this period in 1986, one in Federal waters in 1987, and no explosions through June 1988. Comparison of turtle strandings during periods characterized by high and low numbers of offshore explosions (March-April 1986 vs. March-April 1987 and 1988, respectively) suggested a positive relationship between the frequency of explosions and the stranding of turtles (Fig. 7). Strandings of turtles in western Louisiana (Statistical Area 17) were minimal for 1985 (3 turtles), 1987 (30 turtles) and through June 1988 (3 turtles). However, 119 stranded turtles were reported between 1 May and 30 September 1986.

Two turtles were autopsied that were stranded on beaches within 2 weeks after explosions at monitored platforms.

[2]Andre Landry, Texas A&M University, 5007 Avenue U, Galveston, TX 77551. Personal commun.

One loggerhead showed no characteristics consistent with explosive impacts. External inspection of another loggerhead found dead 2 days following a nearshore explosion revealed a bloated carcass with green flesh and gas bubbles beneath the scutes. Necropsy showed lung hemorrhage, four ruptures of the right atrium, and bloody fluid in the pericardial sac (Landry[2]). Lung hemorrhage is consistent with impacts resulting from underwater explosions; however, this condition, along with ruptures in the heart, may also be the result of postmortem decomposition.

Marine Mammals

Between 19 March and 19 April six dolphins (all *Tursiops truncatus*) stranded in 1985, 41 (40 *T. truncatus* and 1 *Stenella* sp.) in 1986, 22 (*T. truncatus*) in 1987 and 22 (*T. truncatus*) in 1988 in Statistical Area 18. Of these, fifteen dolphins in 1986 and 12 in 1987 were considered either fetuses or newborns (length ≤120 cm). Based on state of decomposition and the reported date of stranding, one adult and two fetal dolphins in 1986 and one adult dolphin in 1987 had died before the 19 March to 19 April sampling period. Only three stranded dolphins were reported in Statistical Area 17 between January 1985 and December 1987. Data are not available for 1988 at this time. Although dolphins may be impacted by explosions, the relationship between the stranding of dolphins and offshore explosions was not as conspicuous (Fig. 8).

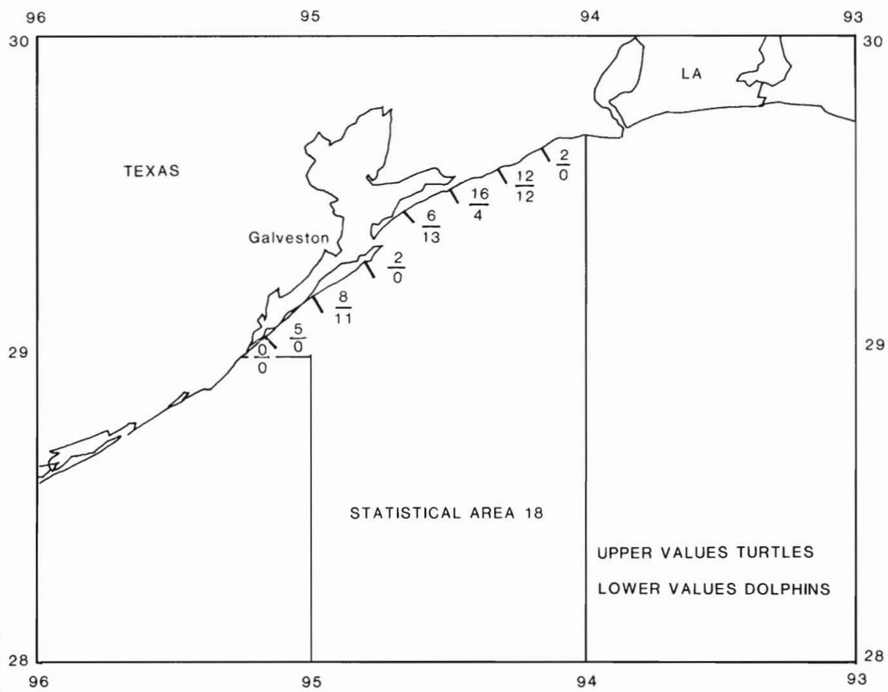

Figure 4.—Reported strandings of sea turtles (upper numerals) and dolphins (lower numerals) in Statistical Area 18 between 19 March and 19 April 1986.

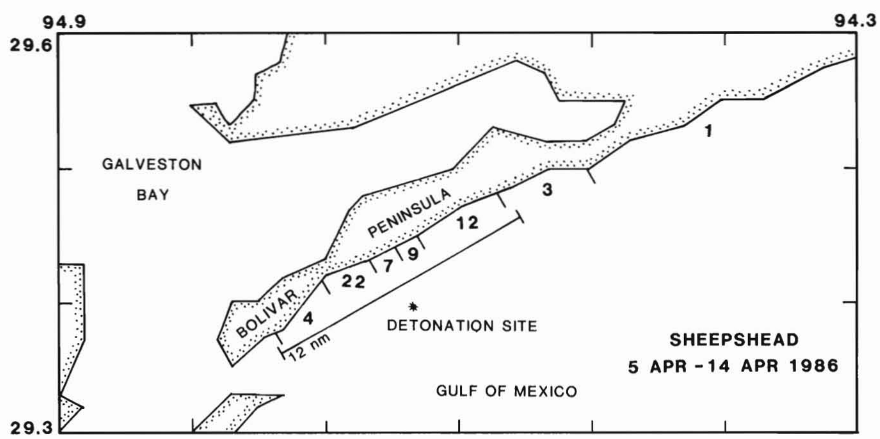

Figure 5.—Strandings of sheepshead reported on Bolivar Peninsula from April 5-19, 1986.

Biological Monitoring at Removal Sites

Turtles

A total of 11 turtles were observed at 7 of 52 removal sites monitored by NMFS (Table 1). One sighting of a green turtle, *Chelonia mydas*, and multiple sightings (4 and 6 observations) of two loggerhead turtles were made over a 4-day period near a platform 135 km off Sabine Pass just prior to its removal on 20-21 July 1986. After the first of six explosions an upside-down, motionless turtle, presumably a loggerhead, was observed drifting downcurrent about 6 m below the surface. Six sightings of loggerhead turtles were reported at five other removal sites, and a single observation of a green turtle, *Chelonia mydas*, was made at a seventh site. Turtles were observed under a variety of conditions ranging from pre- and post-blast helicopter surveys, routine fuel runs for helicopters, and from platforms and motor vessels.

On 1 August 1988 a loggerhead turtle was observed four times by NMFS observers during removal operations at an offshore oil platorm. On 3 August NMFS requested that the petroleum company conduct a diver survey to make sure no sea turtles were in the area prior to any detonations. The divers captured the loggerhead turtle (about 65 cm, straight shell length) apparently sleeping under one of the cross members on the platform. The turtle was brought to the surface, held during detonation activities and eventually released unharmed at another platform. Six days later a turtle of similar size was captured and brought to the surface by NMFS divers during a night dive at the platform at which the first captured turtle was released. The turtle was sleeping on the sea floor under a horizontal plate (mud mat) on the platform that was raised about 40 cm off the bottom. Due to high seas and strong currents, the divers were unable to get the turtle aboard the ship for accurate identification, and the capture attempt was aborted.

Marine Mammals

Between 1 and 100 dolphins were observed at each of 30 of 52 removal sites monitored by NMFS (Table 1). On seven occasions the presence of dolphins delayed the scheduled detonation of explosives from times ranging from 11 minutes to 2 hours. Scaring dolphins with small explosive charges and herding dolphins with boats were not always effective in moving the dolphins away from the detonation site. The minimal effort expended on feeding dolphins to lure them from the removal site was unsuccessful.

Fishes

Dead fish were collected at 48 of 52 removal operations. Estimated fish kills ranged between 0-300 and 0-10,000 at caissons and platforms, respectively. The explosive removal of structures in water depths >20 m killed more fish than at shallower sites. An estimated 1,000-2,500 red snapper, *Lutjanus campechanus*, and several cobia, *Rachycentron canadum*, two species under Federal management, were killed at one removal site where water depth was 42 m. Post-blast samples of fish mortalities showed greater species diversity at deeper sites. The number of fish killed decreased with subsequent explosions at structures requiring multiple detonations.

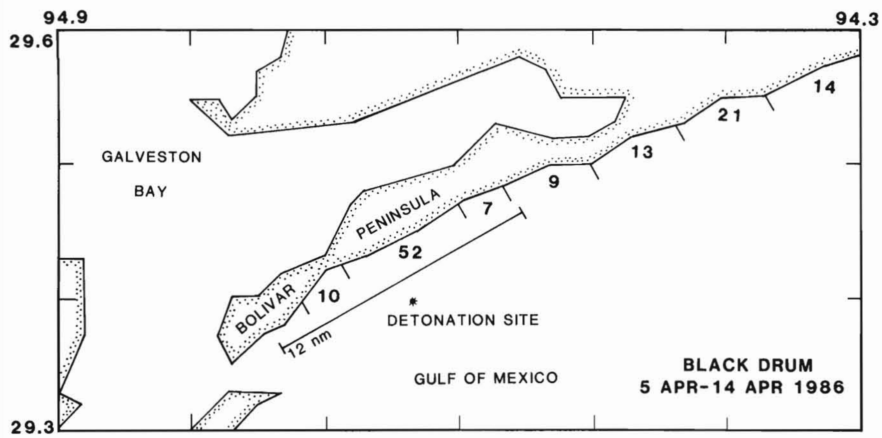

Figure 6.—Strandings of black drum reported on Bolivar Peninsula during 5-19 April 1986.

Exposure of Turtles to an Underwater Explosion

In June 1986, a platform off Bolivar Peninsula, Tex., was removed using 92 kg of explosives. Although in-water measurements of pressure levels were not recorded, values based on mathematical models were estimated to be 221, 217, 213, and 209 decibels (dB) for horizontal distances from the detonation site of 229 m, 366 m, 549 m, and 915 m, respectively (Cummings[1]). Two Kemp's ridleys (6.7 and 0.6 kg) and two logger-

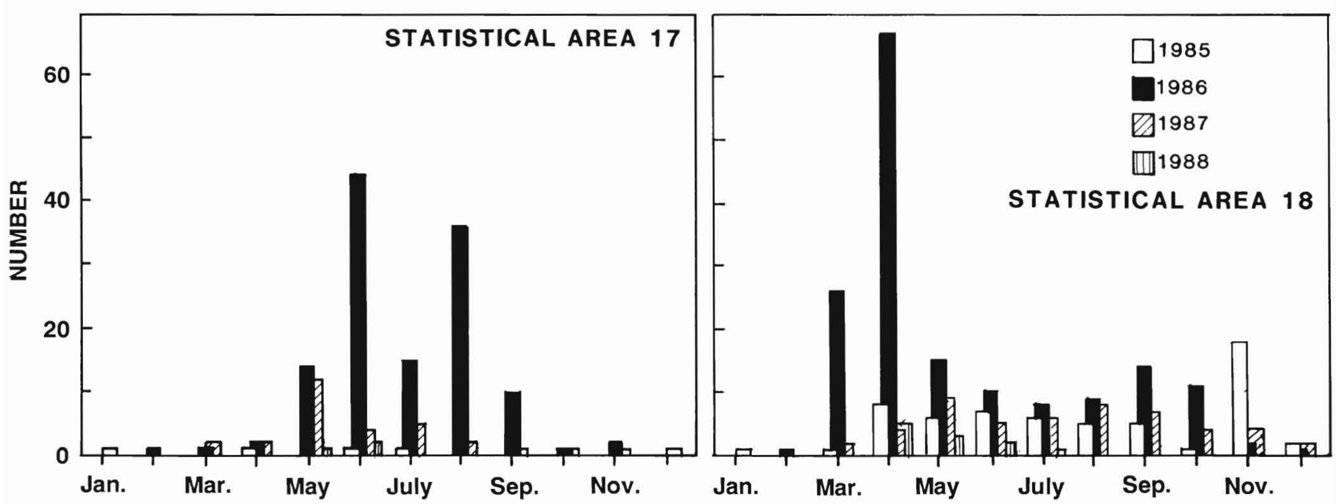

Figure 7.—Frequency of sea turtle strandings reported in Statistical Areas 17 and 18 from 1985 to 5 August 1988. Strandings in 1985 were reported by the public and confirmed by NMFS.

heads (4.2 and 5.5 kg) within 366 m, as well as one loggerhead (6.8 kg) at 915 m were rendered unconscious by a simultaneous explosion of four 23 kg charges. About 2 cm of the cloacal lining everted through the anal opening of the Kemp's ridley (6.7 kg) positioned at 229 m. Ridleys (1.3 and 1.5 kg) at distances of 549 and 915 m were apparently unharmed. Unconscious turtles recovered when removed from the cages. All loggerheads displayed abnormal pink coloration caused by dilated blood vessels at the base of the throat and flippers. This condition continued for about 3 weeks, after which time all turtles appeared normal. These data verified that explosions can result in both near- and far-field injuries to turtles (Table 3).

Supplementary data pertaining to fish were collected in conjunction with these experiments. Sheepshead, Atlantic croaker, *Micropoginias undulatus*; Atlantic bumper, *Chloroscombrus chrysurus*; Atlantic spadefish, *Chaetodipterus faber*; and black drum were found dead floating on the surface at the blast site. Necropsy of dead floating fish revealed internal damage ranging from minor tears in the gas bladder to severe lesions of abdominal organs (Guillen[3]). The same species were subsequently found dead on adjacent beaches. Twenty-nine of 99 drift bottles released at the platform were found in the same beach locality as the fishes within 2 days after the explosion indicating that surface currents probably were strongly directed toward shore. Three of 99 seabed drifters released at the platform were also recovered along the beach.

Review and Discussion

Relation of Strandings to Explosions

Dates and locations pertaining to the use of underwater explosives at offshore oil and gas structures are scattered throughout industry files. No government agency or agencies maintain a complete data base for explosives operations in offshore waters and coastal embayments. It would be a very long, arduous, and costly task to locate these records and compile them into an accurate and useful data base even with the cooperation of everyone involved. But compilation of these data is a prerequisite to comparing sea turtle strandings with the frequency and location of offshore explosions. Nevertheless, there is a striking relationship between the number of strandings which occurred during a period of high vs. low removal activity. Fifty-one turtle strandings occurred in Statistical Area 18 during 19 March-19 April 1986 following 22 nearshore explosions. Four and five strandings occurred during the same period in 1987 and 1988, respectively, when only 1 explosion was reported through July 1988. Thus, it appears that platform removals may have affected the strandings of turtles near Bolivar Peninsula. Although there is not such a striking relationship between the strandings of dolphins and explosive platform removals, more dolphins were found stranded in Statistical Area 18 during the 19 March-19 April time period in 1986, than in 1985, 1987, or 1988.

It is difficult to establish a connection between the stranding of an individual sea turtle and a particular offshore explosion. Turtles found on beaches are usually in such poor condition that it is

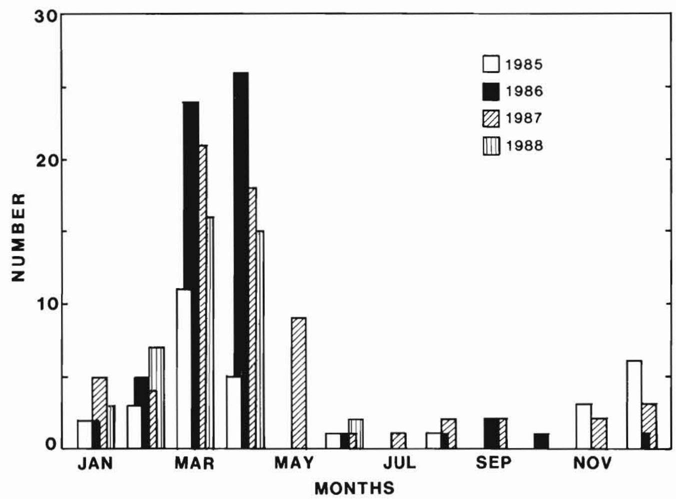

Figure 8.—Frequency of marine mammal strandings reported in Statistical Area 18 from 1985 to June 1988. Strandings in 1985 were reported by the public and confirmed by NMFS.

Table 3.—Description of turtle injuries with respect to distance from explosion and estimated energy level (dB) of shockwave.

Species	Distance from explosion (m)	Estimated energy level (dB)	Injuries: Immediate	Injuries: 1-hour post blast
Lepidochelys kempi	229	221	Unconscious	Vasodilation around throat and flippers; 2 cm of cloaca everted; vasodilation lasted 2-3 weeks.
Caretta caretta	229	221	Unconscious	Vasodilation around throat and flippers; redness around eye and nose; vasodilation lasted 2-3 weeks.
L. kempi	366	217	Unconscious	Appeared normal.
C. caretta	366	217	Unconscious	Normal behavior, but vasodilation present around base of flippers; vasodilation lasted 2-3 weeks.
L. kempi	549	213	None visible	Appeared normal.
C. caretta	549	213	None visible	Appeared normal except for vasodilation around throat and flippers; vasodilation lasted 2-3 weeks.
L. kempi	915	209	None visible	Appeared normal.
C. caretta	915	209	Unconscious	Appeared normal except for vasodilation around throat and flippers; vasodilation lasted 2-3 weeks.

[3]George Guillen, Texas Parks and Wildlife Department, P.O. Box 8, Seabrook, TX 77586. Personal commun.

impossible to determine cause of death even with a necropsy. Dead sea turtles generally sink until decomposition gases float the carcass to the surface 2-3 days later. Consequently, movement of a carcass may not correspond with that of drift cards released after an underwater explosion. Similarly, it is difficult, using surface observations, to document dead turtles immediately after an underwater explosion. A fresh sea turtle carcass placed 3.6 km off the coast of the southeastern United States took 13 days to wash ashore (Murphy[4]). Depending on the magnitude and direction of winds and currents, dead turtles may take weeks to wash ashore. The greater the distance from shore at time of death, the less likely the carcass will reach the beach. In addition, injured turtles are less able to avoid predators or may swim for undetermined distances and times before succumbing to injuries. Murphy[4] also observed sharks feeding on turtle carcasses at sea. Thus, an absence of stranded turtles on the beach is not conclusive evidence that turtles were not injured by offshore explosions.

Relation of Shrimping Effort to Strandings

An increase in turtle strandings did not correspond with an increase in shrimp fishing effort. In Statistical Area 18 strandings were high during March-April 1986. However, shrimping effort in <18 m depths was low during March and April 1985, 1986, 1987, and 1988 (39-388 vessel-days fished, 136-334 days, 107-248 days, and 48-113 days, respectively) while fishing effort was much higher in summer and fall months of June through November (291-1,400 vessel-days fished, 233-702 days, 504-2,350 days, and 457 days through April 1988, respectively).

Turtle strandings increased along the Atlantic coast when the shrimp season opened and fishing effort was high (Murphy[4]). However, low shrimping effort can result in a high incidence of turtle capture and subsequent death in areas where sea turtle density is high. Ogren[5] suggests that the high number of reported captures of juvenile Kemp's ridleys by shrimpers in the mid-1970's may be correlated with high densities of portunid crabs, a primary food source of the Kemp's ridley turtle.

Effects of Explosions

Information about the effects of underwater explosions on sea turtles is extremely limited. O'Keeffe and Young (1984) describe a series of three underwater shock tests conducted by the Naval Coastal Systems Center near Panama City, Fla., in 1981. Despite helicopter surveys for turtles prior to each of three detonations of 544 kg of TNT (Trinitrotoluene) at mid-depth in water about 37 m deep, at least three turtles were found after the explosions. One turtle was killed at a distance of 152-213 m; one turtle at 366 m sustained minor injuries; and one turtle at 610 m appeared to be uninjured. In the absence of other information, O'Keeffe and Young (1984) estimated a safe range of at least 79 m per cube root of turtle weight in kilograms for a 545 kg charge of TNT. O'Keeffe and Young (1984) assumed that shock waves injured the lungs and other organs which contained gas as is known to occur in birds and mammals. Researchers also expected the ear drums of turtles to be sensitive, and smaller turtles to suffer greater injuries from the shock wave than larger turtles.

The above method can be applied to our experiment in which two turtles were placed at each of four distances from an explosion. This yields a predicted safe range beyond 98 m for the smallest turtle (0.59 kg) and a safe range beyond 42 m for the largest turtle (6.82 kg). Predicted ranges assume a 544 kg explosion, although the actual weight totalled only 92 kg. The data show four turtles were rendered unconscious between 229 and 366 m from the detonation. One of these sustained damage to the cloacal lining at 229 m. Another turtle was also rendered unconscious at a distance of 915 m. In this case, the model developed by O'Keeffe and Young (1984) using 544 kg of explosive failed to predict a safe range for turtles.

Experimental animals were revived during the handling required to assess their physical condition. However, in the wild, unconsciousness will render a turtle more susceptible to predation, and the unconscious turtle may sink to the bottom. Although resting turtles can remain submerged for several hours, the effects of submergence on stunned turtles is unknown.

Little information is available on the effects of explosions on marine mammals (O'Keeffe and Young, 1984). Research conducted at the Lovelace Biomedical and Environmental Research Institute on the impacts of underwater explosions on dogs, sheep, and monkeys showed similarities between species for reponse to shock waves as a function of specimen size. Two types of injuries resulted from underwater explosions: Hemorrhaging in and around the lungs and excitation of radial oscillations of small gas bubbles normally present in the intestine (Richmond et al., 1973; Yelverton et al., 1973).

Goertner (1982) developed a computer model to predict distances at which marine mammals exposed to underwater explosions would sustain injuries. The model estimated that an Atlantic bottlenose dolphin calf would suffer slight injury at about 1,189 m from a 544 kg charge of TNT detonated at 38 m in deep water. O'Keeffe and Young (1984) suggested doubling this estimate to provide an adequate margin of safety. Though currently unavailable, models should be developed specifically for sea turtles, and should address conditions encountered in platform removal operations. The magnitude of the impact zone will vary from site to site due to the weight and position (inside or outside piling; above or below mudline) of explosives, water depth, reflectivity of the bottom substrate, and reflectivity of density gradients within the water column. Therefore, existing models require refinement before they can be used with a high degree of confidence to predict safe ranges for turtles.

Since fish aggregate around offshore platforms (Shinn, 1974; Hastings et al., 1976; Jackson et al., 1978; Gallaway and

[4]Sally Murphy, South Carolina Wildlife and Marine Resources Department, P.O. Box 12599, Charleston, SC 29412. Personal commun.

[5]Larry H. Ogren. The biology and ecology of juvenile sea turtles: Kemp's ridley (*Lepidochelys kempi*) in the Gulf of Mexico and the north Atlantic. Unpubl. manuscr.

Martin, 1980; Gallaway and Lewbel, 1982; Tennison, 1985), probably for protection and food, similar factors may operate for sea turtles. Are sea turtles regularly associated with offshore energy structures, or is it only a chance event that turtles may be in the vicinity of a structure when underwater explosives are used?

Data collected at all structure removal sites monitored by NMFS observers from 5 April 1986 through 5 August 1988 show a total of 11 turtle sightings at 7 of 52 structures. Three of these turtles were seen at a single platform in July 1986 by Tim Fontaine[6] who observed them at night apparently feeding on juvenile blue crab, *Callinectes sapidus*, and rock shrimp, *Sicyonia brevirostris*).

A number of turtles have been observed in the vicinity of oil and gas structures in Gulf of Mexico waters off the Texas and Louisiana coasts. Lohoefener[7] reports sighting over 200 turtles during aerial surveys, many in areas characterized by high concentrations of oil platforms. Although the aerial surveys are limited in geographic scope, the information collected to date indicates specific oil platforms where sea turtles have been observed in the northern Gulf of Mexico. Fuller and Tappan (1986) reported two turtles observed by divers at Louisiana oil platforms. One of these, a leatherback, *Dermochelys coriacea*, apparently became entangled under the platform and died. We assume these structures provide a resting place or a location where food is readily available. Diving clubs have reported 27 underwater observations of sea turtles in the northwestern Gulf of Mexico through August 1987. Nine of these were associated with Texas oil platforms (Manzella[8]).

Eight scientific studies conducted in the Gulf of Mexico between 1975 and 1985 offer insights on the distribution and behavior of turtles around natural and artificial reef structures, although the studies did not focus on sea turtles (Rosman et al., 1987). Based entirely on observations by divers, submersibles, and time-lapse photography, underwater sightings of turtles were infrequent. Photographs often showed turtles lying on the sea floor within the confines of the camera assembly. More turtles were photographed at night than during the day. Successive photos suggested that turtles might remain within 3 m of the camera assembly for more than 2-3 hours. One individual loggerhead, identifiable by barnacle patterns on the shell, was seen at the West Flower Garden Bank in the Gulf of Mexico by scuba divers in February, June, and September of 1980. Rosman et al. (1987) suggested the superiority of time-lapse photography over diver observations based on 231 turtle sightings in 25,186 photographs versus 1 sighting in 77 dives in the southwest Florida study.

At the Buccaneer Platform off Galveston, Tex., 4 sightings were reported during 527 research dives between August 1977 and September 1980 (Rosman et al., 1987). Two of the four turtles were lying on the sea bottom in physical contact with the structure. The number of sightings may represent a minimum number of turtles in the area because the attention of divers was not focused on turtles. In a similar situation on 20 August 1987, Gitschlag conducted a task-oriented dive at Buccaneer without sighting a turtle, although Renaud observed one turtle twice within 20 minutes from a dive boat at the surface.

Further evidence that turtles are found around other man-made structures comes from studies at the Florida Power and Light Company's St. Lucie Plant. Between 1976 and 1986, 1,530 sea turtles were entrained through three cooling water inlet pipes (3.7-4.9 m diameter) located 365 m offshore. The species composition of turtles included 86 percent loggerhead, 13 percent green, and about 1 percent leatherback, Kemp's ridley, and hawksbill, *Eretomochelys imbricata*, combined (Florida Power and Light, 1986).

The above data show that turtles are found in the vicinity of offshore structures. However, observation and capture of two loggerhead turtles by NMFS in August 1988 at offshore platforms suggest that loggerhead turtles hide and/or rest on the bottom under these structures. The nature of these associations merit further investigation. Quantification of resident vs. transient turtles, distance at which resident turtles may range from structures, and seasonal abundance in various geographic areas are just a few of the questions which remain to be answered.

It is interesting to note a difference in regulations for installation vs. removal of offshore oil and gas structures. Extensive environmental impact statements are prerequisite to installation of offshore structures. In contrast, prior to 1986 no formal environmental monitoring was required for structure removal, despite the fact that these structures represent more hard substrate habitat than occurs in all the natural reef and hard bank areas off the Louisiana coast (Reggio et al., 1986). If recent estimates are correct, between 1,600 and 2,000 offshore oil and gas structures are to be removed from the Gulf of Mexico by the end of the century. This raises serious questions about the impacts not only of explosives but also of the potential loss of valuable habitat to a wide variety of marine life.

While it is important to continue monitoring the biological impacts of explosive offshore removals, it is also necessary to develop methods to disperse protected marine life from removal sites prior to detonating explosives. Standard procedures could then be implemented to minimize impacts to turtles and dolphins while simultaneously reducing the delays presently affecting the structure removal process.

Conclusions

Although sea turtles and dolphins are found at offshore energy structures, the details of this association have not been thoroughly investigated. No cause and effect relationship between turtle and dolphin mortalities and offshore explosions has been documented because no dead animals have been recovered at removal sites. Fish were killed at all removal sites monitored by NMFS per-

[6]Tim Fontaine, NMFS Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551. Personal commun.

[7]Ren Lohoefener, NMFS Pascagoula Laboratory, 3209 Fredric Str., Pascagoula, MS 39567. Personal commun.

[8]Sharon Manzella, NMFS Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551. Personal commun.

sonnel. Experimentally exposed turtles and, consequently, wild turtles can be injured by underwater explosions. Comparison of turtle stranding data during periods characterized by high and low numbers of offshore explosions suggests a connection between explosions and the number of turtle strandings; data are less supportive of a relationship between explosions and dolphin strandings. The high number of dead turtles stranded in close proximity to nearshore structure removals provides circumstantial evidence that at least some may have been killed by underwater explosions. However, it is apparent that other factors, including capture in shrimp trawls, ingestion of plastic refuse, and entanglement in debris, are also responsible for turtle mortalities.

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