Activities of juvenile green turtles, *Chelonia mydas*, at a jettied pass in South Texas

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Green turtles, *Chelonia mydas*, have a worldwide distribution in tropical and subtropical regions. Primary nesting areas in the Atlantic region are located at Ascension Island, Aves Island, Costa Rica, and Surinam. The east coast of Florida has the largest breeding assemblage in the United States. The species is listed as endangered by the International Union for the Conservation of Nature (IUCN) (Groombridge, 1982) and is listed as threatened in all areas, except for breeding populations in Florida and the Pacific coast of Mexico, which are listed as endangered (National Marine Fisheries Service, 1991).

During most of the nineteenth century, green turtles were abundant throughout Texas, including the lower Laguna Madre (Hildebrand, 1982; Doughty, 1984). Commercial harvest of these turtles peaked in 1890; Texas landings increased to about 2,160 turtles (265,000 kg) from an estimated 89 turtles (10,909 kg) in 1880. By the early twentieth century the fishery had collapsed (Doughty, 1984).

Understanding habitat needs has been recognized as an essential element for successful recovery of sea turtle stocks in the Gulf of Mexico (Thompson et al., 1990). Distribution, movements, and feeding habits of pelagic hatchlings are unknown. Little research has been conducted on sea turtle populations in Texas. Published stranding data suggest that Texas nearshore and inshore waters are important habitats for juvenile and subadult sea turtles (Rabalais and Rabalais, 1980; Manzella and Williams, 1992). Recent tracking and mark-recapture studies on green turtles indicate that jetties and channel entrances along the south Texas coast serve as summer developmental habitats for this species[1,2] (Manzella et al., 1990; Shaver, 1990, 1994). This is supported by higher numbers of sightings in south Texas versus the upper Texas and west Louisiana coasts (Williams and Manzella, 1991).

Turtles using jetties and channel entrances could interact with human activities, such as channel dredging, shrimping, and recreational fishing and boating. The level of such interaction is dependent on the nature and degree of jetty and channel utilization. Studies conducted during 1991[1,2] indicated that green turtles may utilize jetty habitat to a greater degree than other habitats within Brazos-Santiago Pass, on the basis of sightings and the behavior of a single radio-tracked turtle. The objectives of our study were to describe juvenile green turtle movements within Brazos-Santiago Pass, Texas. We hypothesized that juvenile green turtles select jetty habitat over other habitats within Brazos-Santiago Pass.

Materials and methods

Study area

The study was conducted in the Brazos Santiago Pass area, South Padre Island, Texas (Fig. 1). The pass, extending from the tip of the jetties to the western edge of Barracuda and Dolphin Coves, links the Laguna Madre to the Gulf of Mexico. Landry et al.[1] characterized habitat types within the pass. Using their data, we designated four habitats in the pass area.

The jetty habitat extended 10 m from the visible jetty, with water depths up to 3 m. It contained partially exposed and submerged granite boulders and rubble, which decreased in density as distance from the jetty increased. The highest density and concentration of sessile organisms were found in this habitat. Barnacles (*Balanus* sp.), sea urchins (*Arbacia punctulata*), and

[1] Landry, A., Jr., D. Costa, B. Williams, and M. Coyne. 1992. Turtle capture and habitat characterization study. Final Rep. submitted to the U.S. Army Corps of Engineers, Galveston District, 2000 Fort Point Blvd., Galveston, TX 77553, 112 p.

[2] Renaud, M., G. Gitschlag, E. Klima, S. Manzella, and J. Williams. 1992. Tracking of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) sea turtles using radio and sonic telemetry at South Padre Island, Texas. June–September 1991. Final Rep. to the U.S. Army Corps of Engineers, Galveston District, 2000 Fort Point Blvd., Galveston, TX 77553, 52 p.

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three algal species (*Ulva fasciata*, *Podina vickersiae*, and *Bryocladia thysigera*), were the most abundant organisms associated with jetty structure.[1] The near-jetty habitat encompassed areas of barren bottom and scattered boulders on both the Gulf and pass side of the jetty. Channel habitat, the dredged portion of the Brownsville Ship Channel between the jetties, extended seaward from Barracuda and Dolphin Coves to the tip of the jetties. It was characterized by a scoured bottom, nearly void of vegetation. Water depths ranged from 10 to 15.2 m and averaged 12.5 m. Channel width was about 90 m for most of its length. East of the coves, the distance from the jetty to the channel edge ranged from 115 to 152 m. Barren rippled sand, water depths up to 7.5 m, and few organisms were noted within the cove habitat.

Capture of sea turtles

Turtles were obtained from Texas A&M University (TAMU) Institute of Marine Life Science personnel, who were conducting a netting and habitat characterization study at Brazos-Santiago Pass.[3] Turtles were captured either through use of entanglement nets (45.7–91.5 m long, 3.7–7.3 m deep, 12.7 cm bar mesh) set at the Gulf side of the South Jetty, or by encircling a targeted turtle in the shallow coves with the entanglement net. For turtles exhibiting strong site fidelity, 1-m diameter cast nets were used for some captures along the jetties.

Tagging activities

Following capture, turtles were transported 1–2 km to a holding facility where they were kept for 24–48 hours. We recorded turtle weights, straight and curved carapace lengths and widths, and applied radio and sonic transmitters. Telonics radio transmitters (180 g) with 40-cm antennas were fitted with fiberglass to the second neural scute of nine turtles, and Sonotronics sonic transmitters (36 g) were bolted to the posterior marginal scutes. Turtles were designated T1 through T9. The weight of the backpack-type transmitters never exceeded

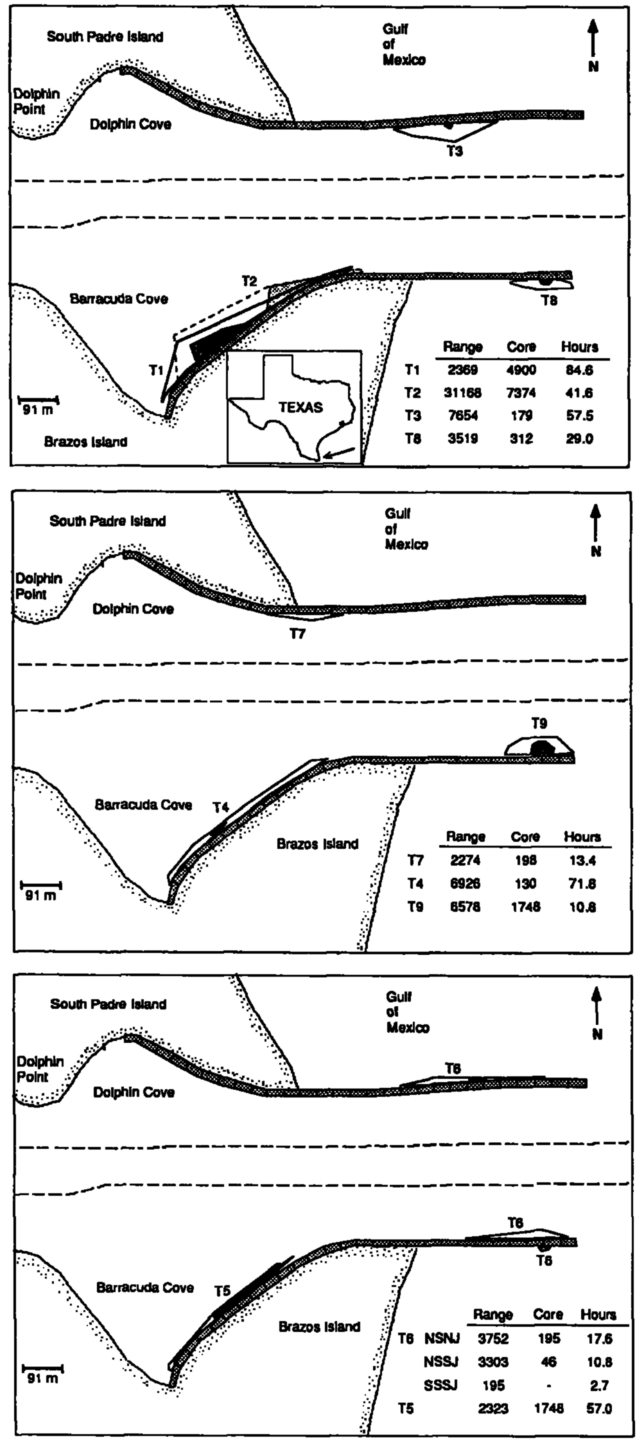

Figure 1

Range (m^2), core area (m^2), and total hours tracked for individual green turtles, *Chelonia mydas*, T1-T9, during August–September 1992. Core area is displayed in solid black and range is enclosed by a solid line for all turtles except T2. T2 has a shaded area representing its core area and a dashed line surrounding its range. For T6, NSNJ = north side of north jetty, NSSJ = north side of south jetty, and SSSJ = south side of south jetty. An inset of the state of Texas with an arrow showing our area of study is located in the upper third of the figure.

[3] Landry, A., Jr., D. Costa, M. Coyne, K. St. John, and B. Williams. 1993. Sea turtle capture and habitat characterization: South Padre Island and Sabine Pass, TX environs. Final Rep. submitted to the U.S. Army Corps of Engineers, Galveston District, 2000 Fort Point Blvd., Galveston, TX 77553, 109 p.

10% of the weight of the turtle, in accordance with the safety recommendations of Brander and Cochran (1969), Bradbury et al. (1979), Aldridge and Bringham (1988), and Byles and Keinath (1990).

Tracking

Turtles were released at their capture sites between 0900 and 1600 hours. We used a Telonics TR2/TS1 receiver-scanner connected to a directional 5-element Yagi antenna to monitor radio transmitters until they became detached from turtles. Maximum radius of signal reception with this equipment is approximately 16 km. When weather prohibited tracking by vessel, turtles were monitored from land. Sonic transmitters were monitored by using a Dukane directional hydrophone with a receiving range between 0.6 and 1.1 km. Sonic tracking alone was used when a turtle had lost its radio transmitter but retained its sonic transmitter or when a second turtle was present in the area of a turtle being monitored by radio.

Data were collected for 12 hours each day. All hours of the day and night were included by offsetting each day's start time by two hours from that of the previous day. We attempted daily to locate every turtle with a functioning transmitter. Up to five turtles were tracked during each day. Geographic location was recorded when a turtle was sighted or its position obtained with sonic telemetry. Reference marks were painted at 50-m intervals on jetty boulders, westward from the seaward tip of each jetty. Locations of turtles were determined with respect to reference marks and to visual estimates of perpendicular distance from the jetties. When possible, turtle locations >40 m from the jetty were recorded by means of a portable global positioning system. The total time spent between jetty reference marks was calculated for each turtle. Each turtle position was given a weight equal to time spent at that position. These weighted positions were then used to calculate a mean position for each turtle. Minimum observation time used for this analysis was 5 minutes. Range (area containing 95% of locations) and core area (area containing 50% of locations) were developed by using the minimum convex polygon method (Mohr, 1947), modified to exclude nonwater areas. To discern differences in movement patterns, the ranges and core areas for each turtle were determined for dawn (0500–0900 h), day (0900–1700 h), dusk (1700–2100 h), and night (2100–0500 h) if at least three days were sampled and >5 h of tracking information were available for a turtle within a time period. To obtain an index of turtle movements, the distance and time between surfacing events were calculated for each turtle and used to estimate mean speed of movements for dawn, day, dusk, night, and all times combined.

Surface and submergence behavior

Surface and submergence times were calculated for each turtle affixed with a radio transmitter. Data collected on the day of release were omitted from analyses of ranges and of surface or submergence behaviors. Surface time was considered to be the interval between the beginning and ending of radio signals (i.e. when the turtle was within 40 cm of the ocean surface). Submergence time was defined as the interval between the end of a radio signal and the beginning of the next signal (i.e. when the turtle was deeper than 40 cm). Overall mean surface and submergence times, and day, night, dawn, and dusk means were calculated for each turtle. A surface or submergence interval overlapping two time periods was included in the period containing the majority of the interval.

Statistical methods

Distribution of variables (surface and submergence times, movement speed) were tested with the Shapiro-Wilk test for normality (α=0.05). The Kruskall-Wallis analysis was used to test for differences in means between dawn, day, dusk, and night (α=0.05) (Sokal and Rohlf, 1981) when the null hypothesis (normal distribution) was rejected. If a significant difference was indicated, a means test described by Conover (1980) was used to determine which means differed, again by using α=0.05.

Results

Sea turtle movement patterns

Nine green turtles (29.1–47.9 cm straight carapace length [SCL], 2.6–14.8 kg) were tracked from 14 to 58 days from 31 July to 26 September 1992 (Table 1). Differences in tracking periods were due to different capture dates and variable tag retention. In addition, on some days certain turtles could not be located owing to inclement weather. All turtles moved away from the jetties immediately following release. Those released between the jetties entered the deeper waters of the channel, but T8, released on the Gulf side of the south jetty, moved south, roughly parallel to the beach. Seven turtles returned to the jetties within an hour. T6 and T7 went offshore after entering the channel and returned to the jetties the next

Table 1

Percent total submergence time (PTST), maximum submergence time (MST, minutes), weight (kg), straight carapace length (SCL, cm), and dates tracked for nine green turtles, *Chelonia mydas*, at South Padre Island, Texas.

Turtle	PTST	MST	Weight	SCL	Date
T1	88.8	24.3	14.8	47.9	31 Jul –26 Sep
T2	92.4	21.4	11.5	44.7	01 Aug–25 Sep
T3	96.3	32.9	3.1	30.1	01 Aug–26 Sep
T4	80.8	31.2	2.7	29.1	01 Aug–26 Sep
T5	90.1	25.4	2.6	29.2	01 Aug–26 Sep
T6	96.3	39.8	3.6	31.5	02 Aug–26 Sep
T7	93.1	25.8	3.9	33.3	06 Aug–26 Sep
T8	96.5	37.8	3.4	31.5	09 Aug–26 Sep
T9	97.8	38.1	4.1	33.0	10 Aug–23 Sep

Table 2

Mean distance (m) moved by hour by time period for nine green turtles, *Chelonia mydas*, tracked near South Padre Island, Texas. A line above mean movements indicates no significant difference (α=0.05).

Turtle		Time of day			
T1	Period	Night	Dawn	Dusk	Day
	Mean distance	127	161	401	251
T2	Period	Night	Dawn	Day	Dusk
	Mean distance	8	148	440	568
T3	Period	Dusk	Day	Dawn	
	Mean distance	20	102	323	
T4	Period	Night	Dusk	Dawn	Day
	Mean distance	25	223	243	330
T5	Period	Night	Day	Dawn	Dusk
	Mean distance	45	144	108	191
T6	Period	Dusk	Day		
	Mean distance	59	225		
T7	Period	Night	Dawn	Day	
	Mean distance	9	496	517	
T8	Period	Dawn	Dusk	Day	
	Mean distance	171	195	201	
T9	Period	Day	Dawn		
	Mean distance	114	149		

day. Seven turtles remained in the general area of their capture throughout the study period. Of the others, T6 used three areas along both jetties and T7 moved extensively along both jetties before moving up the channel and into South Bay. Only data from the pass were used in analyses for T7.

Daily movements of turtles along the jetties ranged from less than 50 m to more than 1,000 m. Mean rate of movement ranged from 8 m/h to 568 m/h (Table 2). The least movement occurred at night, ranging from 8–127 m/h. Seventy percent of all locations were within 5 m of the jetties. Only 0.3% were within channel boundaries, including five channel crossings. Overall areal ranges of turtles remaining in the jetty area were from 2,274 to 31,168 m^2. Overall core areas ranged from 130 to 7,374 m^2.

Five of the nine turtles tracked had ranges restricted to the north side of the south jetty (Fig. 1). Northerly winds, in excess of 20 knots, coincided with the movement of T6 from the windward side of the north jetty into protected waters near the south jetty by day 14. Mean locations for three turtles (T1, T4, and T5) were within 400 m of the Barracuda Cove beach. The mean location of T2 was about 650 m from the beach, about halfway up the jetty. The only turtle that had significantly different mean locations for different time periods was T1 ($P<0.05$). The mean dusk location of T1 was about 250 m closer to the jetty tip than its mean dawn and day locations and over 400 m closer than its mean night location. T3, on the south side of the north jetty, also showed greater westward movement at night than at any other time ($P<0.05$).

Submergence and surface behavior

Tracking was conducted for a total of 108 hours at dawn, 247 h during the day, 60 h at dusk, and 151 h at night. Time spent submerged ranged from 80.8 to 97.8% and averaged 91% for all turtles (Table 1). Submergence time ranged from 0.02 to 39.8 minutes. Overall mean submergence time varied from 1.9 to 6.1 min between turtles. Surface time ranged from 1 to 1,146 seconds. Overall mean surface time varied from 8.5 to 26.5 seconds.

A breakdown of submergence time by turtle revealed that 99% of all turtle submergences were <20 min, 74–96% were <10 min, and 38–64% were <1 min (Fig. 2). Submergence patterns were significantly different when data were analyzed by dawn, day, dusk, and night (Table 3). The number of submergences >10 min was higher at night than at other time periods for every turtle tracked at night.

A breakdown of surface time by turtle revealed that 99% of all turtle surfacings were <120 sec, 67–92% were <15 sec, and 41–77% were <5 sec (Fig. 2). Surface patterns also were significantly different when

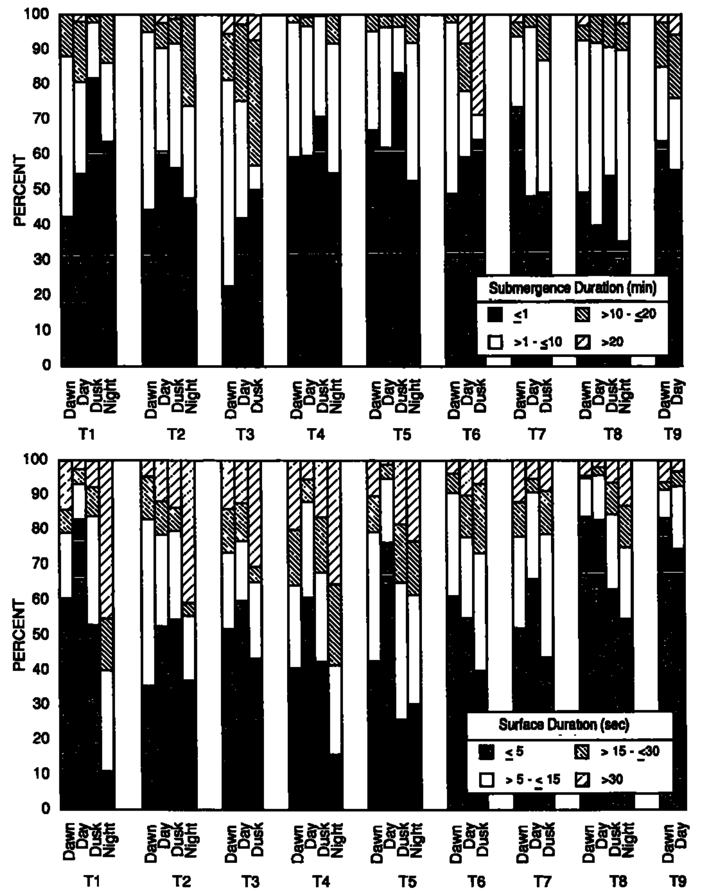

Figure 2

Green turtle, *Chelonia mydas*, submergence and surface durations by specified time intervals in hours, dawn (0500–0900), day (0900–1700), dusk (1700–2100), and night (2100–0500).

data were analyzed by dawn, day, dusk, and night (Table 3). The number of surfacings >15 sec was higher at night than at other periods for every turtle tracked at night. The mean surface time was significantly higher at night than at all other time periods for four of six turtles tracked at night.

Discussion

Movements and habitat use

Habitat use by juvenile green turtles in the Brazos-Santiago Pass was not proportional to available habitat.[1,2] The jetty habitat, which contained extensive algal mats, received a disproportionately high amount of use, suggesting that turtles possibly congregated there for food. Analysis of stomach contents of juvenile green turtles by Landry et al.[3] support the utilization of algal food sources. Turtles in this study were seen feeding on algal growth along the jetties, especially at dusk. The abundance of food may account for the high site fidelity and small core areas. Other studies of similar-size green turtles described their food source as algae (Wershoven and Wershoven, 1989; Wershoven and Wershoven, 1991), both algae and sea grasses (Burke et al., 1991), and primarily sea grasses (Ogden et al., 1983). Mendonca (1983), working with larger turtles (7.8–54.5 kg) postulated that green turtles prefer sea grass. Sea grasses were present within 1 km of the jetty habitat of our study area.[4] One turtle from our study entered and remained in a sea grass habitat for over a month; however, no fecal or stomach samples were taken while it was in this habitat. Bjorndal et al. (1991) suggested that green turtles possess gut microflora for digestion of both algae and seagrass and that the relative abundance of microbial species would vary in response to longterm changes in diet. Therefore, turtles could take advantage of a local abundance in either food source.

All of the turtles in this study had small ranges of movement. A juvenile green turtle tracked at the jetties in 1991 also showed limited movements.[2] The most limited movements were at night, suggesting that resting was most common at night. This hypothesis is supported in studies by Bjorndal (1980), Mendonca (1983), and Ogden et al. (1983) who documented resting areas for turtles at night coupled with a shorter range of movements compared with activity during the day. Mendonca (1983) noted that during summer months the resting sites of green turtles on consecutive nights were within meters of the previous night's rest site. The reason for the westward movements of T1 at night is unknown. The more sheltered jetty habitat adjacent to the cove may have been preferred for resting at night, whereas a broader stretch of the jetty was utilized for daytime foraging activities. Turtles at the jetties apparently have an abundant food source in proximity to resting sites. In contrast, Mendonca (1983) recorded areal ranges of 0.48 to

[4] Quammen, M., and C. Onuf. 1991. Laguna Madre: seagrass changes continue decades after salinity reduction. Rep. to the National Wetlands Center, U.S. Fish Wildl. Serv., Campus Box 39, 6300 Ocean Dr., Corpus Christi, TX 78412, 27 p.

5.06 km^2 for juvenile green turtles. Ogden et al. (1983) found turtles moved up to 0.5 km between feeding and resting sites, but they did not report ranges of movement.

Turtles appeared to select for the south jetty. Landry et al.[3] also recorded many more turtle sightings at the south jetty than at the north jetty. Of two turtles caught at the north jetty, only one remained there longer than two weeks. The other moved to the south jetty during northerly winds in excess of 20 knots. Because of its accessibility, the north jetty received much more use by the public than the south jetty. The effect of this disproportionate use on turtle presence or behavior, or both, during the study is unknown.

Submergence behavior

Green turtle behavior was characterized by numerous short submergences and surfacings. Submergences ≤5 min occurred mostly during dusk and dawn when active periods of foraging were observed. We felt this was a direct effect of the shallow habitat occupied by the turtles. The transmitter antenna could be exposed at times when the turtle was still submerged. Submergence ≥10 min was observed at night and minimally during the afternoon.

Submergence durations by green turtles in our study was similar to that for green turtles studied by Renaud et al.[2] Eighty-nine to ninety-nine percent of the submergences were <10 min in duration and 17–56% were <1 minute. Mean submergence times for turtles in our study were considerably shorter than the mean submergence times of Kemp's ridleys found by Byles (1989) (18.1 min), and Mendonca and Pritchard (1986) (16.7 min). This may be a result of the different habitats and feeding behaviors of Kemp's ridleys and the green turtles in our study. Our turtles also were smaller than turtles in the other two studies.

The percentage of submerged time for each 24-h day ranged from 80.8–97.8%. The turtles with the three lowest percent submerged times were observed for long periods with their antenna only partially exposed. This behavior undoubtedly lowered their submerged to surface ratio. Balazs (1994), through satellite telemetry, found that two migrating adult green turtles in the Pacific Ocean spent 95–96% of their time submerged. Renaud and Carpenter (1994) found percent submerged time to be 90.0–95.7% for three satellite-tracked juvenile loggerhead turtles, *Caretta caretta*, in the Gulf of Mexico. Two satellite-tracked juvenile Kemp's ridley sea turtles, in the Atlantic and Gulf of Mexico, had percent submerged times of 94.0–98.6% (Renaud, in press). Byles (1989), studying adult Kemp's ridleys in the Gulf of Mexico with satellite telemetry, found that they spent an average 96% of the time submerged. A study of radio-tracked loggerheads with 64.0–91.9 cm carapace length (straight or curved not specified) in the Canaveral Channel, Florida, revealed that they averaged 96.2% of the time submerged (Kemmerer et al., 1983).

Table 3

Mean surface and submergence times (nearest sec) by time period, for nine green turtles, *Chelonia mydas*, tracked near South Padre Island, Texas. A line above mean values indicates no significant difference (α=0.05). D = day; K = dusk; N = night; W = dawn.

Turtle		Time of day			
T1	Surface	D5	K11	W13	N47
	Submerge	K60	N172	W214	D236
T2	Surface	D15	K21	W10	N26
	Submerge	D142	K143	W153	N320
T3	Surface	D12	W13	K16	N56
	Submerge	D327	W366	K446	N1371
T4	Surface	D19	K24	W29	N35
	Submerge	K58	D102	W108	N169
T5	Surface	D5	W13	K19	N20
	Submerge	K70	D102	W109	N187
T6	Surface	W7	D11	K15	N80
	Submerge	W125	D321	K501	
T7	Surface	D9	K12	W14	
	Submerge	W123	D145	K184	
T8	Surface	D5	W6	K9	N13
	Submerge	K171	D174	W175	N258
T9	Surface	W6	D6		
	Submerge	W212	D313		

Channel use

During our study, turtles remained primarily near the jetties, probably because food was abundant there and virtually absent in the channel and barren bottom areas. Turtles were found in the channel <0.3% of the time. They appeared to use the channel for transit to other areas or as presumed escape cover.

Conclusions

Our data, combined with numerous sightings of turtles at the jetty[3] and with the fact that there was no appreciable movement away from the jetties by tracked turtles, support the hypothesis that juvenile green turtles in Brazos-Santiago Pass, south Texas, selected for jetty habitat over other habitats available. If this pattern is consistent for all times that green turtles inhabit the pass, then it would indicate that potential harm from hopper dredging or channel boat traffic would be minimal. Our study included only nine turtles and was limited to August–September 1992. Therefore, caution should be used in extrapolating our results to other years or times of the year. The study was timed to coincide with the period of highest turtle abundance in the pass. Data gathered by TAMU indicate that use of the pass by green turtles increases during June–September.[1,3] Turtles appear to be rare from December to March and gradually begin to increase in numbers starting in April. We were unable to monitor turtle behavior during dredging, because no dredging was done during the study; therefore, we do not know how dredging of the channel may affect behavior of turtles occupying the jetty habitat.

Because green turtles are herbivorous, there is very little danger of hook and line captures from jetty fishing. The greatest impact on turtle behavior may be simply that of human activity on the jetties. The level of that impact is currently unknown. We encourage further study, particularly during other times of the year.

Acknowledgments

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