REPORT ON

THE 2000 GREEN TURTLE PROGRAM

AT TORTUGUERO, COSTA RICA

Submitted to
Caribbean Conservation Corporation
and
the Ministry of Environment and Energy of Costa Rica.
14 February 2001

by
Jeff Mangel, Field Coordinator
Sebastian Troëng, Research Coordinator
and
Luciano Segura, Research Assistant
Melinda Stockmann, Research Assistant
Andrés Ortega, Research Assistant
Catalina Reyes, Research Assistant
Zunilda Hudgson, Research Assistant
Alvaro Opazo, Research Assistant
Luis Fernández, Research Assistant
Ricardo Hernández, Research Assistant
Damien Hussy, Research Assistant
Manuel Ramírez, Research Assistant
Sylvia de la Parra, Research Assistant
Mery Martínez, Research Assistant
Reem Hajjar, Research Assistant
Eddy Rankin, Track Surveyor

CARIBBEAN CONSERVATION CORPORATION

Address:	**Apartado Postal 246-2050**	**4424 NW 13th St. Suite A-1**
	San Pedro	**Gainesville, FL 32609**
	COSTA RICA	**USA**
Ph:	**INT+ 506 224 9215**	**INT+ 1 352 373 6441**
Fax:	**INT+ 506 225 7516**	**INT+ 1 352 375 2449**
Email:	**sebastian@cccturtle.org**	**ccc@cccturtle.org**
Webpage:	**http://www.cccturtle.org**	**http://www.cccturtle.org**

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ACKNOWLEDGMENTS

The 2000 Green Turtle Program was conducted under a research permit from the Ministry of Environment and Energy of Costa Rica detailed in resolution Nº 147-2000.

The research assistants Luciano Segura (Argentina), Melinda Stockmann (USA), Andrés Ortega (Colombia), Catalina Reyes (Colombia), Zunilda Hudgson (San Andres), Alvaro Opazo (Uruguay), Luis Fernández (Venezuela), Ricardo Hernández (Venezuela), Damien Hussy (France), Manuel Ramírez (Costa Rica), Sylvia de la Parra (USA), Mery Martínez (Colombia) and Reem Hajjar (Canada) worked long hours to collect the data presented in this report. They were supported by a large group of program participants whose help and financial assistance are gratefully acknowledged.

Tortuguero Conservation Area (ACTo) staff under the professional direction of Sr. Eduardo Chamorro made sure that illegal harvest of nesting turtles and their eggs was virtually non-existent along large sections of the Tortuguero beach during the 2000 green turtle nesting season. They were supported in their dangerous duty by rural guards, coast guards and staff from other conservation areas. Maria Elena Herrera and Eduardo Chamorro of ACTo provided information on park visitation, turtle walks and funds raised.

Fredy Piedra, station manager, made everyone feel at home and made sure that all needs for the green turtle program were addressed. Wagner Quirós and Alexander Castillo, visitors center administrators, provided support at all times. William Perez and Melvin “Pajarito” Bustos provided transport in a timely manner and maintained the field station. Zelmira Williams and Gloria Benlys worked hard to cook delicious Caribbean food for the hungry turtle taggers. The staff of Delta Security patrolled the field station and made sure everyone was safe at night. Manjula Tiwari, Luciano Soares, Katy Garland, Amy Smith, Christy Smith and the birdbanders Pablo Herrera, Andrea Kudrez, Bud Widdowson, Dan van der Broek and Bob Frey participated in nightly patrols and contributed to the friendly atmosphere at the field station.

Eddy Rankin conducted all track surveys. The villagers of Tortuguero provided support and asked questions at all times. The Tortuguero school children and teachers took part in the nightly tagging work. Christian, José, Tony, Rubier, Glenn and Isaias were particularly enthusiastic. The tour guides were positive and provided useful information throughout the green turtle program. The cabinas and hotel owners provided information about the capacity of their establishments. Sr. José Alberto Montano provided information on funds raised by the development association and their planned activities.

Roxana Silman and Ileana Vargas of the CCC office in San José made the green turtle program possible by always being supportive and providing everything necessary. Dan Evans, David Godfrey and Cindy Taft of the CCC office in Gainesville always provided support and information when requested. Dr. Anne Meylan and Dr. René Marquéz kindly provided tag return information. Dr. Jeanne Mortimer, Dr. George Balazs and Manjula Tiwari provided useful comments on the draft report.

EXECUTIVE SUMMARY

Monitoring and Research Activities Conducted

1. A total of 50 track survey along the entire 18 miles of beach between Tortuguero river mouth and Jalova lagoon were carried out between January and December 2000.
2. Peak green turtle nesting was recorded 31 August when 2,386 green turtle nests were counted. A total of 12.9 % of all green turtle nests were deposited between the Tortuguero river mouth (mile –3/8) and the mile 5 marker.
3. Illegal harvest was recorded only during two track surveys with 3 and 4 green turtle poached, respectively.
4. Jaguars killed a minimum of 60 green turtles between 5 April and 11 November.
5. Low levels (0-3 nest per night) of hawksbill nesting were recorded from May to October with a peak in mid-June.
6. During 2,014 hours of night patrols between 9 June-27 October, a total of 1,286 green turtles were newly tagged, 502 green turtles with tags from previous years or other projects and 811 renesting green turtles were recorded.
7. Tagging efficiency for nightly patrols varied between 0-60 % with a mean of 14.4 % (st.dev.=15.1), for nights preceding track surveys (n=20).
8. Probability of within season tag loss from first to last encounter was 0.031±0.013 and varied with research assistant applying the tags.
9. One green turtle captured and tagged in marine areas close to Zapatilla Cays, Panama and one green turtle originally tagged in Mexico were encountered during night patrols.
10. A total of 69.6 % of green turtle nests were deposited in the open zone (n=1,406), 26.4 % were laid in the border zone (n=533) and 4.0 % in the vegetation zone (n=81).
11. Newly tagged green turtles had evidence of old tag holes or notches in at least one front flipper in 8 % of cases (n=106 of 1,265).
12. Ten hawksbills were newly tagged, one hawksbill with tags from 1998 and one renesting hawksbill were recorded.
13. Tissue samples were collected from ten hawksbills. The samples were exported (with appropriate CITES permits) to Dr. Peter Dutton of National Marine Fisheries Service.
14. Mean green turtle carapace length was 104.5 cm CCLmin and 98.2 cm SCLmax. Mean clutch size was 114.3 eggs.
15. Precision of the carapace measurements collected during repeated encounters with the same green turtle was higher for SCLmax than for CCLmin.
16. Mean carapace length for hawksbills was 84.0 cm SCLmax.
17. Green turtles with fibropapillomas represented 6.1 % of carefully examined females (n=12 of 197). Tumors (n=16) varied in size between 1-5.2 cm with a mean of 2.9 cm.
18. A total of 194 green turtle nests were monitored and fate, hatching success and emerging success determined. Overall hatching success was 74.0 % (16,181 empty shells from 21, 861 eggs) and overall emerging success was 71.0 % (15,532 emerged hatchlings from 21,861 eggs).
19. Comparison between excavations and egg counts at the time of laying showed a mean difference of 4.5 eggs (st.dev=18.6) more eggs counted at the time of laying.
20. Mean green turtle nest depth at excavation was 56 cm from the sand surface to the top egg and 71 cm from the sand surface to the bottom of the egg chamber.

21. Mean incubation period for green turtle nests was 57 days (n=110).
22. Unhatched twins and seriously deformed embryos accounted for 0.04 % of all green turtle eggs.
23. The angular range of green turtle hatchling tracks for undisturbed nests was 58º (st.dev.=28º) and the angular range minus outliers was 47º (st.dev.=25º).
24. A total of 6 hawksbill nests were monitored and fate, hatching success and emerging success determined. Overall hatching success was 48.9 % (445 empty shells from 910 eggs) and overall emerging success was 47.8 % (435 emerged hatchlings from 910 eggs).
25. Mean hawksbill nest depth at excavation was 40 cm from the sand surface to the top egg and 57 cm from the sand surface to the bottom of the egg chamber.
26. November was the month with highest rainfall and September the month with lowest rainfall during the 2000 Green Turtle Program.
27. Increased shading caused a decrease in sand temperature and also decreased the range of temperatures. Temperatures at 70 cm varied 5.4ºC in the open zone, 3.6ºC in the border and 3.0ºC in the vegetation zone.
28. The ground water level did not reach sufficiently high levels to drown nests in the border or vegetation zones, in front of the field station (mile 2 5/8).
29. The number of visitors to the CCC Natural History and Visitors Center increased to 24,574 in 2000.
30. New entrance fees and an improved control system has significantly increased the amount of revenue raised by the Tortuguero Conservation Area (ACTo) to ¢59,595,400 (approx. US$188,000) for the first ten months of 2000.
31. Several of the hotels increased their room capacity in 2000 but one hotel slightly decreased capacity due to renovation.
32. A total of 20,824 tourists received permits to go on turtle walks in 2000. Tour guides raised their fee to US$10 per person.
33. The Tortuguero Development Association raised ¢3,190,400 from 15,952 tourists going on turtle walks. The funds will be used to construct a village kindergarten.
34. Four surveys to determine extent of artificial lights visible on the beach were conducted July-October. The intensity of artificial lights had increased at mile 6/8-mile 1 3/8.
35. Satellite transmitters were attached to six green turtles. Four green turtles migrated to Nicaragua, one to Honduras and one to Belize after completing nesting.
36. Satellite transmitters were attached to two hawksbills. Both hawksbills migrated to Nicaragua after completing nesting.
37. Four RAs conducted additional track surveys between Tortuguero river mouth and the mile 5 marker between 9 August-1 October (no surveys 15 and 20 August and 14 September). The proportion of nests deposited in the open zone is inversely correlated to sand temperature and the proportions of nests deposited in the border and vegetation zones are positively correlated to sand temperature.
38. RA Luciano Segura conducted a study on the effects of sand temperature and nest depth on emergence success for 29 green turtle nests laid 8 August 2000 to 2 October 2000. No significant correlations between sand temperature at 40 and 63 cm depth and emerging success, or nest depth and emerging success were found.
39. RA Damien Hussy conducted jaguar track surveys and concluded that at least two jaguars are present on the Tortuguero beach.

Conclusions

1. The vast majority of green turtle nests were deposited 15 June-1 November.
2. Low nesting density at mile 2-3 may be due to the presence of artificial lights behind the beach.
3. Illegal harvest was very low during the 2001 Green Turtle Program thanks to the protection provided by the dedicated Tortuguero park rangers.
4. The large number of green turtles killed by jaguars that was recorded may in part be due to increased survey effort between mile 5 and mile 8 4/8 by graduate student Manjula Tiwari and her assistant Luciano Soares.
5. Night patrols coincide with the period when the vast majority of green turtle nests are laid and no change in night patrol effort is suggested.
6. The low tag loss was due to the proficiency of the RAs and the field coordinator.
7. The low tagging efficiency was due to the high green turtle nesting density.
8. Fibropapilloma incidence does not appear to be exclusively correlated to flipper tagging.
9. The high hatching and emerging success observed in 2000 is encouraging and may have been the result of low sand temperatures, lack of flooding and efficient nest protection by park rangers.
10. Artificial lights located in front of the village are increasing in number and intensity and may affect nesting density along the northern section of the Tortuguero beach.

Recommendations

1. Maintain effort for nightly tagging patrols at the same level.
2. Determine if parasitic marine leeches commonly observed at the tagging site on the flippers, present a threat to female turtles.
3. The practice to collect both curved and straight measurements should be continued.
4. An effort should be made to tag as many male turtles as possible.
5. Monitoring of fibropapilloma incidence should be a priority.
6. Rechargeable batteries for use in the flashlights should be acquired.
7. More durable plastic sheathing to wrap around the flashlights should be acquired.
8. Better quality pencils for data recording should be acquired.
9. Compasses with finer grading to determine hatchling orientation should be acquired.
10. The study of spatial distribution of green turtle nests conducted by four RAs should be repeated and sand moisture should be measured to determine if it is the controlling factor for the proportion of nests deposited in each beach zone.
11. Research into the Tortuguero jaguar population should be encouraged.
12. Another turtle carapace (from a jaguar kill) should be collected, conserved and displayed at the CCC Natural History and Visitors Center.
13. The development of a plan to shield artificial lights should be considered.
14. A study to determine the impact of the number of turtle walk tourists on sea turtle nesting and non/nesting activity should be encouraged.
15. The development of an English word list for distribution to the park rangers should be encouraged.
16. Post season updates should be posted in the village and at the CCC Natural History and Visitors Center.
17. Satellite transmitter attachments and tracking events should be repeated during future green turtle programs.

1. INTRODUCTION

Studies of green turtles (*Chelonia mydas*) at Tortuguero were initiated by Dr. Archie Carr in 1954 (Carr et al. 1978). Since 1959, the Caribbean Conservation Corporation (CCC) has been implementing an annual green turtle program. The protocol for monitoring was revised by CCC staff and Scientific Advisory Committee in preparation for the 1998 nesting season. The new protocol is implemented in order to fulfill CCC's scientific mission in Tortuguero: "*CCC will provide the scientific information necessary to conserve the populations of sea turtles that nest at Tortuguero, Costa Rica, so that they fulfill their ecological roles*". The 2000 Green Turtle Program represents the third year of implementing the new monitoring protocol.

The objectives of this report are to summarize and discuss the results of the 2000 Green Turtle Program and provide recommendations for future monitoring, research and conservation activities in Tortuguero.

2. METHODS

2.1 Preparations

The Research Assistants (RAs) arrived in Tortuguero on 10 June 2000. During the first week they were given lectures on sea turtle biology, the monitoring protocol, station rules and other information relating to the green turtle program. Practical training in tagging and data collection were provided along the northern five miles of beach as well as further into the national park, between miles 13 and 15 (15-16 June).

The mile markers along the northern five miles were repaired and painted during the first days of the Green Turtle Program. The same mile marker positions were used as during the 2000 Leatherback Program (Troëng et al. 2000).

2.2 Track Surveys

Track surveys were conducted approximately weekly during the entire green turtle program. Eddy Rankin conducted track surveys from Tortuguero river mouth (mile -3/8) to Jalova lagoon (mile 18). The surveys begun at dawn (4:30-5:00 AM) at Tortuguero village and finished at 9:30-10:00 AM by Jalova lagoon. The beach section between Tortuguero river mouth and village was surveyed in the afternoon the same day by the same person or in the early morning by a second person. Only tracks from the previous night were recorded and for each track were recorded: species, mile section, half moon or nest, and if the turtle was depredated or not. Dead turtles were considered depredated by jaguars if they were surrounded by jaguar tracks or showed characteristic jaguar injuries. A turtle was considered poached if the track indicated that humans had dragged the turtle off the beach.

2.3 Tagging of Nesting Sea Turtles

Tagging teams patrolled the beach every night between 9 June-27 October (except for 10 June, 12 June, 14 June and 14 October). The number of teams varied from one to five, depending on the number of research assistants and program participants resident at the field station. The northern five miles of beach was divided into two sections: mile -3/8 to the field

station (at mile 2 5/8) and the field station to the mile 5 marker. Each section was patrolled by separate teams and by different teams at 8-12 PM and 12-4 AM, when the number of station residents allowed.

Every encountered turtle that had finished nesting was checked for old tags. Turtles without old tags were tagged in each front flipper, axillary, proximal to the first scale. Species, mile section, tagger, nest zone (open, border, vegetation, or did not lay) and special characteristics or injuries were noted for each tagged turtle.

Tags used during the 2000 Green Turtle Program include National Band&Tag Company (NBTC) Inconel #681 tags no. 85671-85672, 85705-85932, 85938-85950, 86001-89000 and Monel #49 tags no. 79569, 79587, 79601, 79609, 79612-79614, 79616 and 79618.

2.3.1 Green turtles

A sample of green turtles without old tags were tagged using Inconel #681 tags. An effort was made not to mix Inconel and Monel tags on the same individual. In some cases, this meant applying a new Monel tag to an individual carrying only one old Monel tag that could not be removed.

Probability of tag loss was calculated for green turtles tagged with two Inconel #681 tags and subsequently encountered with one or two tags. The probability of tag loss is $1-K_i=1-((2r_{di})/(r_{si}+2r_{di}))$ where K_i is the probability of retaining a tag during the interval i, r_{di} is the number of turtles encountered carrying two tags at interval i and r_{si} is the number of turtles encountered carrying one tag at interval i (Wetherall 1982). Probability of tag loss was estimated for first-to-last encounter.

2.3.2 Hawksbills

Hawksbills (*Eretmochelys imbricata*) were tagged with Inconel #681 tags. A disposable razor blade was used to collect tissue samples from hawksbills. The samples were kept in ethanol at the field station until a CITES permit was obtained and the samples could be sent to Dr. Peter Dutton of the National Marine Fisheries Service, for analysis. The tagging team always remained with the hawksbill until it had returned to the sea and thoroughly deleted its track afterwards.

2.3.3 Leatherbacks

The only leatherback (*Dermochelys coriacea*) encountered during the 2000 Green Turtle Program already carried two tags.

2.4 Biometric Data Collection

2.4.1 Green turtles

Biometric data were collected from a subsample of nesting green turtles. An attempt was made to count 1-2 clutches per night as the eggs were laid. The person counting the eggs would wear a plastic glove so as not to contaminate the nest. Eggs were counted using an egg counter.

All tagged turtles were measured after they had finished nesting, if time allowed. Curved carapace length minimum (CCLmin), from where the skin meets the carapace by the nuchal notch to the posterior notch between the supracaudals, along the midline, was determined to the closest millimeter using a fiberglass measuring tape. Straight carapace length maximum (SCLmax), from the anteriormost edge of the carapace to the posterior tip of the longest supracaudal, was determined, to the closest millimeter, using a set of calipers. Both CCLmin and SCLmax were taken three times by the same person, whose name was recorded in the field book, in order to determine the precision of the measurements. Precision is defined as the difference in cm between the longest and the shortest of the three measurements.

2.4.2 Hawksbills

All hawksbills encountered during nightly tagging work were measured. The clutch was counted, if the hawksbill had not already started to oviposition at the time of encounter.

2.4.3 Leatherbacks

For leatherbacks, CCLmin (from where the skin meets the carapace by the notch of the neck to the posterior end of the caudal projection, next to the central ridge) was measured using two 150 cm fiberglass measuring tapes stapled together.

2.5 Fibropapilloma Assessment

2.5.1 Green turtles

The green turtles, for which clutches were counted, were also examined for fibropapillomas. All soft body parts, including the cloacal region were examined, using a flashlight with red filter. The absence or presence of fibropapillomas, location and size of fibropapillomas and persons examining the turtle were recorded.

2.6 Determination of Nest Survivorship and Hatching Success

A sample of green turtle and hawksbill nests was marked during oviposition. The nests were marked with three pieces of flagging tape. The third piece of flagging tape was used to make up for pieces of flagging tape that may be lost as a result of camouflaging turtles, feeding insects or persons removing the flagging.

The distance from the nest to the vegetation and to the latest high tide line (in some cases to the current water line) was recorded when the nest was marked.

Marked nests were inspected daily. Inspection of a nest ceased after it had been excavated. Depredated and dug-up nests were monitored until 65 days after laying before excavation of the nest. If hatching was observed, the date was noted and the nest was excavated two days later. If no hatchlings or hatchling tracks were observed the nest was excavated after approximately 65 days. Nests were not excavated if the excavator encountered a large number of hatchlings in the nest. If a few hatchlings were encountered, they were placed in a shallow hole and covered with sand so that they could reach the sand surface and emerge the following night. Nests that could not immediately be found were located by probing for soft sand using a wooden stick (after hatching and emerging had taken place). This technique greatly aided in locating many of the marked nests.

Date laid, date excavated, date hatched (if available), mile section, excavator, nest code, distance from sand surface to top egg, distance from sand surface to bottom of egg chamber, empty shells, live hatchlings, dead hatchlings, unhatched eggs with no embryo, unhatched eggs with visible embryo (all stages before fully developed), unhatched eggs with full embryo (ready to hatch but not yet pipped), pipped eggs, depredated eggs, destroyed eggs and yolkless eggs were recorded for each excavated nest.

In case a nest could not be found, an attempt was made to determine the fate of the nest. Nests were considered poached if an empty egg chamber was encountered. Nests were assumed dug-up by another turtle if broken eggshells and a new bodypit were encountered where the nest was supposed to be located. Nests were considered depredated if a large number of eggshells were found in close proximity to the location of the marked nest. If human footprints and digging was observed at the location of the nest, the nest was considered dug-up by tour guides. Nests for which the fate could not be determined with certainty were excluded from the sample.

2.7 Physical Data Collection

2.7.1 Rainfall

Rainfall (to the closest mm) was recorded daily at 9 AM at John H. Phipps Biological Field Station.

2.7.2 Air temperature

Air temperature (current, minimum and maximum) was recorded daily at 9 AM at John H. Phipps Biological Field Station.

2.7.3 Sand temperature

Sand temperature was measured using dataloggers located at 30, 50 and 70 cm depth in the open, border and vegetation zones in front of the field station.

2.7.4 Ground water level

The level of the ground water was measured daily at 9 AM. The water level was determined from the water level in three PVC pipes (8.5 cm x 160 cm) dug down in front of the John H. Phipps Biological Field Station, at 5, 10 and 15 m distance from the high tide line (as of 15 March 1998).

2.8 Collection of Human Impact Data

2.8.1 Visitors to Tortuguero

The number of visitors to the CCC Natural History and Visitors Center was estimated from the number of paying tourists that entered the center. The number of tourists visiting Tortuguero National Park was estimated from the number of visitors that paid the entrance fee at the National Park offices at Cuatro Esquinas, Tortuguero and Jalova.

2.8.2 Capacity of hotels and cabinas

The cabina owners and hotel managers provided information on the room and bed capacity of their respective establishments.

2.8.3 Turtle walks

The number of tourists going on turtle walks was estimated from the permits issued to tour guides by Tortuguero Conservation Area (ACTo). The Tortuguero Development Association recorded the money raised from tour guide fees, to be used for community projects.

2.8.4 Artificial lights

Artificial lights were monitored along the northern 5 2/8 miles of beach. Light surveys were carried out when no moon was visible. The mile section, light source and location (beach side or lagoon side) were recorded for each artificial light.

2.8.5 Hatchling orientation

Hatchling orientation was determined for a sample of nests from which hatchlings had emerged the previous night. The observer, mile section, distance from the nest to the sea (m), the approximate number of tracks, the angular range of the tracks 10 m from the nest (^{o}), the angular range minus outlier at 10 m distance from the nest (^{o}) and the modal direction at 10 m from the nest (^{o}) were determined for each hatched nest, using a compass.

2.9 Additional Research

In addition to the regular monitoring activities, several research projects were conducted during the 2000 Green Turtle Program. Many of these projects were undertaken by independent researchers and will be reported on separately, by the same researchers, in compliance with their research permits. Projects completed by CCC staff and research assistants are reported on below.

2.9.1 Satellite transmitters

Between 18-20 July, two hawksbills and two green turtles were fitted with satellite transmitters after they had completed nesting. Each turtle was released once the transmitter was attached. Four green turtles were fitted with satellite transmitters in the same fashion, between 17-20 September.

The hawksbills are being tracked as part of a research project coordinated by the U.S. National Marine Fisheries Service (NMFS) that is tracking hawsbill migrations from nesting beaches throughout the wider Caribbean.

CCC is conducting the green turtle migration study in partnership with Dr. Anne Meylan of the Florida Marine Research Institute, with technical assistance provided by NOAA/National Marine Fisheries Service researchers Barbara Schroeder and George Balazs, and with collaboration of the Ministry of Environment and Energy of Costa Rica (MINAE).

The satellite tracked turtles were named in honor of respected long time Tortuguero residents, by the research assistants and by Tortuguero school and high school students. Maps of the satellite tracked turtles' migration paths, regularly updated by Dan Evans, are on display at the CCC webpage (http://www.cccturtle.org).

Funding for the project was provided by the U.S. NOAA/National Marine Fisheries Service and additional funding for the Sea Turtle Migration-Tracking Education Program has been provided by the Disney Wildlife Conservation Fund, the Geraldine R. Dodge Foundation, the Elizabeth Ordway Dunn Foundation, the Educational Foundation of America and the Kenneth A. Scott Charitable Trust (A Key Bank Trust).

2.9.2 Additional nest census by Andrés Ortega, Catalina Reyes, Luciano Segura and Melinda Stockmann

For the period 9 August-1 October (with the exception of 15 and 20 August and 14 September) four of the RAs conducted daily track surveys between Tortuguero river mouth (mile –3/8) and the mile 5 marker. Censuses were conducted each morning beginning at 4:30 to 5:00 AM. The number of nests by zone (open, border or vegetation) and the number of aborted nesting crawls ('half moon' or 'DNL') were recorded for each 1/8th mile section of beach.

Percent nests in each zone were tested for correlation with sand temperature at 70 cm depth in the corresponding zone using Pearson Correlation (Zar 1999).

2.9.3 Study on the effects of temperature on emerging success by Luciano Segura

Sand temperature data were recorded from ten green turtle nests in the border zone and 19 in the open zone, laid in the northern 5 miles of Tortuguero beach from 8 August 2000 to 2 October 2000. Two thermocouples were buried at a depth of 40 cm (nest top) and 63 cm (mid-clutch) at approximately 50 cm from the nest. Thermocouples were placed in the sand 51 or 53 days after the eggs were laid and were removed two days after hatching. Temperatures were taken between 14:30 hours and 16:30 hours to coincide with mean daily sand temperatures (Horikoshi 1992). Nests were excavated two days after hatching and nest depth, hatching and emergence success was determined. For this study, mean nest temperature was calculated from four days prior to hatching and the two days following hatching. Least squares regression analysis was used to determine relationships between the different factors. The t-test was used to compare means. SPSS 7.5 software was used for analyses.

2.9.4 Jaguar track survey by Damien Hussy

Research assistant Damien Hussy with assistance of Manjula Tiwari and Luciano Soares collected data on jaguar activity on the beach, between 1 October-1 November. Data were collected during daily nest checks for mile 2 5/8 to mile 8 4/8 and during weekly turtle track surveys from miles 2 5/8 to mile 18. Jaguar track size, direction of travel, distance of travel along the beach, entry and exit points from the forest and turtle kills were recorded. Photographs were also taken of jaguar tracks and forwarded to jaguar researcher Mrs. Carolyn Miller to aid in a regional initiative to identify individual jaguars from their tracks.

2.10 Environmental Education Activities

Regular environmental education activities were prepared for the Tortuguero primary and high schools. Talks and slide shows about sea turtle biology, conservation and environmental economics were given opportunistically to groups staying at or passing by the field station. A group of students from Universidad de Costa Rica in Limón participated in the program 24-28 September.

3. RESULTS

3.1 Track Surveys

3.1.1 Green turtles

Green turtle nesting was observed from March to December with the main nesting season extending June-October (Figure 1). Peak green turtle nesting was recorded 31 August when the track surveyor counted 2,386 green turtle nests (Figure 1).

The highest density of green turtle nests was encountered at mile 9-12 with peak nesting at mile 10 (Figure 2). Green turtle nests laid between the Tortuguero river mouth (mile –3/8) and the mile 5 marker, where almost all nightly tagging was conducted, accounted for 12.9 % of all green turtle nests (Figure 2).

Illegal harvest of green turtles from the beach was very low during the 2000 nesting season (Figure 3). Such illegal harvest was mainly limited to the very end of the nesting season in late October-early November when regular night patrols by park rangers had been terminated (Figure 1, Figure 3). Illegal harvest was only recorded during two track surveys and only 3 and 4 turtles were poached respectively (Figure 3).

Notes and anecdotal information on illegal harvest are summarized in Appendix 3.

Jaguars killed at least 60 green turtles between 5 April and 11 November (Figure 4). Turtle carcasses were found between miles 3 5/8 and 15 5/8. In 24 cases it was noted that the jaguar had flipped the turtle onto its carapace. In 22 instances the turtle was dragged into the forest (either on the day of the kill or the following day).

Based on the variations in track size it is possible that there are several jaguars that kill turtles in the National Park. Jaguar tracks indicate that the animals would often walk along the beach for long stretches (more than 1 mile). Tracks were also noted emerging from and re-entering the forest, as close as just south of the village of Tortuguero (mile 3 3/8). Researchers spotted the jaguar on or just behind the beach at two occasions - 29 August (seen twice) and 15 October.

3.1.2 Hawksbills

Very low levels of hawksbill nesting were observed from May to October with a peak in mid-June (Figure 5).

3.1.3 Leatherbacks

Leatherback nesting occurred from February to early July with peak nesting in March (Figure 6).

3.2 Tagging of Nesting Sea Turtles

3.2.1 Green turtles

A total of 1,286 newly tagged green turtles, 502 carrying tags from previous years and 811 renesters were recorded during 2,014 team hours of night patrols (Appendices 1&2). This represents a sample of females coming ashore to nest and also includes seven male green turtles tagged when washed up during copulation (the last male was tagged 5 August).

Table 1. Probability of within-season tag loss from first-to-last encounter:

a) by tagger

Tagger	**R_{di}**	**r_{si}**	**1-K_i±95% CL**
RA1	62	0	0±0
RA2	5	0	0±0
RA3	4	0	0±0
RA4	4	0	0±0
RA5	3	0	0±0
RA6	2	0	0±0
RA7	1	0	0±0
RA8	1	0	0±0
RA9	1	0	0±0
RA10	52	1	0.010±0.019
RA11	34	1	0.014±0.029
RA12	45	2	0.021±0.030
RA13	18	1	0.027±0.054
RA14	33	3	0.039±0.045
RA15	35	3	0.041±0.047
RA16	32	3	0.045±0.052
RA17	21	5	0.102 ±0.091
RA18	4	1	0.111 ±0.221
RA19	4	1	0.111 ±0.221
RA20	9	3	0.143 ±0.163
TOTAL	**376**	**24**	**0.031±0.013**

RA=Research Assistant, r_{di}=number of green turtles encountered with two tags, r_{si}=number of green turtles encountered with one tag, 1-K_i=probability of tag loss, 95%CL=95% confidence limits

b) by month

Month	**R_{di}**	**R_{si}**	**1-K_i±95% CL**
June	26	1	0.019±0.038
July	135	9	0.032±0.021
August	165	10	0.030±0.019
September	49	3	0.030±0.034
October	1	1	0.333±0.629
TOTAL	**376**	**24**	**0.031±0.013**

r_{di}=number of green turtles encountered with two tags, r_{si}=number of green turtles encountered with one tag, 1-K_i=probability of tag loss, 95%CL=95% confidence limits

For green turtles coming ashore between Tortuguero river mouth and the mile 5 marker (nests + half moons), tagging efficiency varied between 0 % and 60 % with an average of 14.4 % (st.dev.=15.1), for nights preceding track surveys (n=20).

Two tag returns from green turtles tagged outside of Costa Rica were recorded during the Green Turtle Program. One turtle was encountered nesting at Tortuguero on 12 August 2000 and was originally tagged 20 July 2000 by Drs. Meylan at Zapatilla Cays, Bocas del Toro province, Panama (A. Meylan pers. comm.). Another green turtle was encountered emerging on the beach at Tortuguero on the night of 9 July 2000 and carried a tag attached in Mexico. However, according to Mexican records the tag number recorded belong to a Kemp´s ridley (*Lepidochelys kempii*) (R. Marquéz pers. comm.).

A total of 69.6% of green turtle nests were deposited in the open zone (n=1406), 26.4% in the border zone (n=533) and 4.0% in the vegetation zone (n=81).

Newly tagged green turtles had evidence of old tag holes or notches in at least one front flipper in 8 % of cases (n=106 of 1,265). Marine leeches were occasionally observed around the tag site on tagged turtles.

The probability of within-season tag loss was 0.031±0.013 (Tables 1a&1b). Within-season tag loss varied with tagger (Table 1a) but remained fairly constant between months of tagging (Table 1b).

3.2.2 Hawksbills

Ten hawksbills were newly tagged, one hawksbill carrying tags from 1998 and one renesting hawksbill were encountered (Appendices 1&2). Twenty percent (2 of 10) of the newly tagged hawksbills had evidence of being previously tagged.

Tissue samples from ten hawksbill females were exported to Dr. Peter Dutton of National Marine Fisheries Service (USA) for genetic analysis.

A total of 50 % of hawksbill nests were deposited in the open zone (n=6), 25% in the border zone (n=3) and 25% did not lay on when they were encountered (n=3).

3.2.3 Leatherbacks

The only leatherback encountered was tagged earlier in the 2000 nesting season, on the beach in the Pacuare Nature Reserve, located to the south of Tortuguero National Park (B. Dick pers.comm.).

The leatherback nested in the open zone (n=1).

3.3 Biometric Data Collection

3.3.1 Green turtles

The mean size of nesting green turtles was 104.5 cm CCLmin and 98.2 cm SCLmax (Table 2). Mean clutch size was 114.3 eggs per clutch (Table 2).

The three male green turtles measured when washed up during mating were smaller than the average nesting female green turtle (Table 2).

Table 2. Carapace length and clutch size of green turtles.

Sample	n	× CCLmin ± ST.D. (cm)	n	× SCLmax ± ST.D. (cm)	n	× Clutch size ± ST.D. (eggs)
Females – Tortuguero	1704	104.5 ± 5.0	1626	98.2 ± 4.6	165	114.3 ± 25.6
Males – Tortuguero	3	98.8 ± 2.7	1	94.4	N/A	N/A

Precision of the carapace measurement was higher for research assistants than for program participants (Table 3a). Precision during more than one encounter was higher for the straight carapace measurement than for curved length (Table 3b).

Table 3. Precision of carapace measurements for green turtles:
a) during the same encounter

	CCLmin			SCLmax		
Observer	**n**	**×±ST.D.**	**Range**	**n**	**×±ST.D.**	**Range**
Research Assistants	1683	0.2 ± 0.2	0-2.0	1908	0.2 ± 0.2	0-3.8
Participants	787	0.3 ± 0.3	0-1.9	448	0.3 ± 0.3	0-1.8
TOTAL	**2470**	**0.2 ± 0.2**	**0-2.0**	**2356**	**0.2 ± 0.2**	**0-3.8**

b) during more than one encounter

	CCLmin			SCLmax		
Encounters	**n**	**×±ST.D.**	**Range**	**n**	**×±ST.D.**	**Range**
2	346	1.1±0.8	0.1-5.3	323	0.8±0.7	0.1-5.3
3	113	1.5±0.7	0.3-4.1	111	1.2±0.7	0.3-4.7
4	39	2.0±1.0	0.5-5.0	31	1.6±0.6	0.6-3.0
5	4	2.5±0.8	1.9-3.6	4	1.5±1.2	0.8-3.2
6	3	2.5±1.1	1.5-3.6	3	1.1±0.5	0.7-1.6
7	1	2.3±N/A	N/A	N/A	N/A	N/A

3.3.2 Hawksbills

The mean straight carapace length for hawksbills was 84.0 cm (n=9) (Table 4).

Table 4. Carapace length of hawksbills.

Sample	n	× CCLmin ± ST.D. (cm)	n	× SCLmax ± ST.D. (cm)
Females – Tortuguero	11	89.0 ± 3.4	9	84.0 ± 2.1

For hawksbills, the precision of the straight carapace length was higher than the precision of the curved length measurement (Table 5).

Table 5. Precision of carapace measurements for hawksbills.

Sample	CCLmin (cm)			SCLmax (cm)		
	n	**×**	**Range**	**n**	**×**	**Range**
Females – Tortuguero	9	0.3	0.1-1.0	7	0.2	0.1-0.4

3.3.3 Leatherbacks

The leatherback measured 156.7 cm CCLmin.

3.4 Fibropapilloma Assessment

3.4.1 Green turtles

Twelve green turtles with fibropapillomas were encountered, representing 6.1% of carefully examined females (n=197). For three of the affected turtles the tumors were located on the right front flipper, five turtles had tumors on the left front flipper and one turtle had a tumor on the neck. The remaining affected turtles had tumors on the neck and right front flipper, neck and right rear flipper, and right and left front flippers. Tumors varied in size from 1 cm to 5.2 cm with a mean of 2.9 cm (n=16).

Four of the affected turtles carried tags from previous years, one of the newly tagged turtles with tumors had an old tag hole, the remaining seven newly tagged turtles with fibropapillomas lacked evidence of previous tagging.

3.5 Determination of Nest Survivorship and Hatching Success

Coatis (*Nasua narica*), domestic dogs (*Canis familiaris*) and a tayra (*Eira barbara*) were seen excavating nests, depredating eggs and hatchlings during the Green Turtle Program. Black vultures (*Coragyps atratus*) and turkey vultures (*Cathartes aura*) were observed depredating eggs and hatchlings from nests that had been opened by other predators or nesting turtles. The vultures also depredated inactive hatchlings during the day. Magnificent frigate birds (*Fregata magnificens*) and a juvenile common black-hawk (*Buteogallus anthracinus*) were observed depredating hatchlings moving down the beach. Ghost crabs (*Ocypode quadrata*) dug into nests, depredated eggs and hatchlings scrambling towards the sea. Maggots or fly larvae (*Megaselia scalaris*) were observed depredating eggs, pipped hatchlings and hatchlings in the nest. Ants were observed depredating or killing eggs, pipped hatchlings, hatchlings in the nest and hatchlings in the vicinity of the nest.

3.5.1 Green turtles

A total of 206 green turtle nests were marked. The flagging tapes were removed or lost for 7 of these nests and tour guides excavated 5 additional nests. As the hatching and emerging success of these nests can not be determined with certainty they have been excluded from further analysis, leaving a total of 194 green turtle nests which were monitored and excavated (Table 6&7).

To estimate overall hatching and emerging success, it is assumed that monitored nests contained a mean of 111.8 eggs (= mean number of eggs in undisturbed excavated nests) with the exception of flooded nests which contained a mean of 119.3 eggs and the two nests together which contained 246 eggs. The total number of nests is 187 nests plus 6 flooded nests plus the two nests located together (Table 6&7). Hence, overall hatching success was 74.0 % (16,181 empty shells from a total of 21,861 eggs) and emerging success 71.0 % (15,532 emerged hatchlings from 21,861 eggs).

A comparison between excavations and egg counts at laying for undisturbed nests (n=97) shows a mean of 4.5±18.6 more eggs (range: +73 to -50 eggs) counted at laying.

Table 6. Fate, hatching and emerging success of marked green turtle nests.

Fate	Public n	Park n	Total n	% of total	Hatching success (%)	Emerging success (%)
Undisturbed						
1. Undisturbed.	79	64	143	73.7	89.2	87.6
Disturbed						
2a. Poached.	5	0	5	2.6	0	0
2b. Empty egg chamber.	4	1	5	2.6	3.9[a]	3.9[a]
3. Flooded.	3	3	6	3.1	90.9[b]	45.3[b]
4a. Depredated by dogs.	1	3	4	2.1	0.2	0.2[c]
4b. Depredated by mammals.	5	12	17	8.8	17.7	17.7[c]
4c. Depredated by ants.	1	0	1	0.5	87.7	60.8[c]
5. Dug up by nesting turtle.	4	8	12	5.2	42.4	40.7
6. Two nests together.	1	0	1	1.5	98.4[d]	96.7[d]
TOTAL	**103**	**91**	**194**	**100**	**74.0**	**71.0**
(7. Excavated by tour guides after hatching.	3	2	5)			
(8. Undetermined.	5	2	7)			

[a]Assuming a mean nest size of ×=111.8 eggs
[b]Flooded nests contained a mean of 119.3 eggs/nest
[c]Assuming that all hatchlings unaccounted for, had emerged before depredation
[d]The two nests together contained 246 eggs

Table 7. Results of nest excavations.

Fate	Empty shells	Pipped eggs	Live hatchlings	Dead hatchlings	Unhatch. Embryo	Unhatch. full embryo	Unhatch. no embryo	Depredated	Destroyed	Yolkless
1	14261	188	120	143	247	251	798	237	0	34
2a	0	0	0	0	0	0	0	0	0	0
2b	22	0	0	0	0	0	0	0	0	0
3	651	8	12	315	18	1	34	4	0	2
4a	1	0	0	0	0	0	10	10	0	0
4b	337	18	1	0	9	1	63	26	0	0
4c	98	0	0	30	5	0	6	0	0	0
5	569	6	1	22	9	1	40	15	0	0
6	242	2	2	2	0	0	2	0	0	0
ALL	**16181**	**222**	**136**	**512**	**288**	**254**	**953**	**292**	**0**	**36**

For fate, see codes in Table 6.

The distance from the sand surface to the top egg after hatchling emergence for undisturbed nests (n=141) varied between 21-99 cm with a mean of 56 cm. The distance from the sand surface to the bottom of the egg chamber for the same nests varied between 35-103 cm with a mean of 71 cm. The incubation period for undisturbed green turtle nests for which emerging was observed (n=110) varied between 47-76 days with a mean of 57 days.

Green turtle nests were poached mainly in the vicinity of the village (located at mile 2 7/8-mile 3 3/8) and between the village and the river mouth (mile -3/8) (Figure 7). Few nests were poached inside Tortuguero National Park (Table 6). Depredation of nests by mammals

(almost exclusively coatis) was more common in the National Park than on the public beach (Table 6). Nesting turtles dug up more nests in the National Park (Table 6), where nesting density is higher, than on the public beach (Figure 2).

Marked nests deposited in the vegetation zone (n=13) were left undisturbed in 54 % of cases, 71 % of marked nests in the border zone (n=49) and 76.5 % of marked nests in the open zone (n=132) were left undisturbed. Marked nests depredated by mammals (n=17) were located in the vegetation and border zones in 53 % of cases, and 47 % were located in the open zone.

Unhatched twins and seriously deformed embryos accounted for 0.04 % of all green turtle eggs (Table 8).

Table 8. Incidence of albinism, twins and deformed embryos.

	n	**% of total eggs**
Albinos	0	0
Twins	2	0.01
Deformed embryos	6	0.03
TOTAL	**8**	**0.04**

3.5.2 Hawksbills

Undisturbed hawksbill nests (n=3) had a mean distance from the sand surface to the top egg of 40 cm (range: 38-44 cm) and a mean depth from the sand surface to the bottom of the egg chamber of 57 cm (range: 54-67 cm). The fate of monitored hawksbill nests and results from nest excavations are summarized in Table 9. Overall hatching success for monitored hawksbill nests was 48.9 % (445 hatchlings from 910 eggs) and emerging success was 47.8 % (435 hatchlings emerged from 910 eggs).

Table 9. Results of hawksbill nest excavations.

Fate	Nests (n)	Shells	Pipped	Live hatchl.	Dead hatchl.	Unhatch. Embryo	Unhatch. full embryo	Unhatched no embryo	Depred.	Total eggs	Hatching success	Emerging success
1	3	328	27	9	1	26	8	53	13	455	72.1	69.9
2a	1	0	0	0	0	0	0	0	0	N/A	0	0
7	2	117	1	0	0	8	1	28	2	N/A	38.6[a]	38.6[a]

Fate 1=Undisturbed, 2a=Poached and 7=Dug up by nesting turtle
[a]Assuming a mean nest size of ×=151.7 eggs

3.5.3 Leatherbacks

No leatherback nests were monitored during the Green Turtle Program.

3.6 Physical Data Collection

3.6.1 Rainfall

November was the month with the highest rainfall and September the month with the lowest rainfall during the Green Turtle Program (Table 10).

Table 10. Rainfall, January-November 2000.

Month	Total rainfall (mm/month)	× rainfall (mm/24hrs)
January	545.1*	22.7
February	363.3**	12.5
March	128.6	4.1
April	435.1***	14.5
May	506.3**	16.3
June	572.7	19.1
July	549.5**	17.7
August	575.0**	18.5
September	139.0	4.6
October	533.2**	17.2
November	617.3**	20.6

* No data for 1-7 January

**Data for 48 hours for 22-23 February, 25-26 February, 4-5 May, 24-25 May, 28-29 May, 10-11 July, 14-15 July, 23-24 July, 28-29 July, 7-8 August, 14-15 October, 26-27 November

***Data for 72 hours for 25-27 April

3.6.2 Air temperature

September was the month during the Green Turtle Program with the highest mean maximum air temperature (Table 11). August and November were the months with the lowest mean maximum air temperature (Table 11).

Table 11. Air temperature, January-November 2000.

Month	× minimum temp. (^{o}C) *	× maximum temp. (^{o}C) *
January	22.6*	28.1*
February	22.8*	30.0*
March	23.5	32.6
April	24.2*	33.3*
May	24.8*	32.8*
June	24.5	31.0
July	24.5	31.4
August	25.4*	30.6*
September	25.3*	33.5*
October	24.6	30.8
November	25.0*	30.6*

*No data for 1-7 January, 22 February, 25 February, 4 May, 24 May, 28 May, 10 July, 14 July, 23 July, 28 July, 25-26 April, 7 August, 15 October, 26 November

3.6.3 Sand temperature

For the Green Turtle Program, July and November were the month with lowest mean monthly sand temperature (Table 12, Figure 8). Mean monthly sand temperatures were highest in September (Table 12, Figure 8).

Increase in shading by plants caused a decrease in sand temperature and also decreased the range of the sand temperature as seen when comparing sand temperatures in the open zone with sand temperatures in the border and vegetation zones (Figure 8). For 9 June-30

November the sand temperature at 70 cm depth ranged 5.4°C in the open, 3.6°C in the border and only 3.0°C in the vegetation zone (Figure 8).

Table 12. Mean monthly sand temperatures.

	Field station			**Field station**			**Field station**		
Zone	Open	Open	Open	Bord.	Bord.	Bord.	Veg.	Veg.	Veg.
Depth (cm)	*30*	*50*	*70*	*30*	*50*	*70*	*30*	*50*	*70*
January, × temp (ºC)	26.4	26.2	26.2		25.1	25.1	24.5	24.3	24.4
February, × temp (ºC)	27.8	27.6	27.5		26.4	26.2	25.2	25.1	25.2
March, × temp (ºC)	29.1	28.8	28.4	(28.5) [b]	27.2	26.9	26.4	26.0	25.9
Retrieval depth (cm) 12 March	*32*	*55*	*72*		*50*	*71*	*29*	*47*	*65*
Depth (cm) 12 March	*30*	*50*	*70*	*30*	*50*	*70*	*30*	*50*	*70*
April, × temp (ºC)	29.9[a]	29.9[a]	29.9[a]	28.3	28.2	28.1	27.6	27.3	27.2
May, × temp (ºC)	30.2	30.1	29.9	28.1	28.0	28.0	27.4	27.2	27.2
June, × temp (ºC)	29.0	29.0	29.1	27.3	27.4	27.5	26.7	26.6	26.8
Retrieval depth (cm) 2 July	*34*	*53*	*75*	*28.5*	*50*	*70*	*30*	*51*	*68.5*
Depth (cm) 2 July	*30*	*50*	*70*	*30*	*50*	*70*	*30*	*50*	*70*
July, × temp (ºC)	28.7	28.5	28.5	27.1	27.2	27.1	26.6	26.5	26.6
August, × temp (ºC)	29.5	29.4	29.3	27.5	27.6	27.6	26.9	26.9	26.9
September, × temp (ºC)	31.9	31.3	30.9	28.7	28.8	28.6	27.8	27.6	27.5
Retrieval depth (cm) 26 Oct.	*30*	*49.5*	*70*	*32.5*	*52*	*69*	*31*	*49*	*67.5*
Depth (cm) 26 Oct.	*30*	*50*	*70*	*30*	*50*	*70*	*30*	*50*	*70*
October, × temp (ºC)	30.0	30.1	30.3	27.5	28.0	28.2	26.7	26.9	27.1
November, × temp (ºC)	28.9	28.8	28.7	27.2	27.2	27.2	25.9	25.9	26.1
Retrieval depth (cm) 2 Dec.	*30*	*52*	*72*	*30.5*	*51*	*70*	*29*	*50*	*71*

[a] High tides washed out the dataloggers located in the open zone on 15 April. The dataloggers were relocated in the open zone (5 m closer to the vegetation line) on 16 April and then moved back to the original position on 2 December; [b] Data from 12 March onwards

3.6.4 Ground water level

During the Green Turtle Program, the ground water level reached sufficiently high levels to be noticed in the PVC pipes (Figure 9). At none of these occasions did the ground water reach levels that could drown green turtle nests located in the border or vegetation zones, in front of the field station (Figure 9).

3.7 Collection of Human Impact Data

3.7.1 Visitors to Tortuguero

The number of visitors to the CCC Natural History and Visitors Center increased to 24,574 tourists in 2000 (Table 13).

May and June are the months with least visitors arriving to Tortuguero (Table 13). More tourists visited the Visitors Center in 2000 than during 1998 or 1999 (Table 13).

The number of paying visitors to Tortuguero National Park (TNP) increased to 34,605 tourist for the first ten months of 2000 (Table 14).

Table 13. Visitors to the CCC Natural History and Visitors Center.

	1998		1999		2000	
Month	**Total**	**× Per Day**	**Total**	**× Per Day**	**Total**	**× Per Day**
January	2086	67	2282	74	1681*	67
February	2024	72	1967	70	2427	84
March	1812	58	2068	67	2582	83
April	1953	65	1475	49	1742	58
May	852	27	1006	32	1365	44
June	1432	48	1093	36	1437	48
July	2555	82	2567	83	2899	94
August	2809	91	2740	88	2645	80
September	1565	52	1640	55	1871	62
October	1006	32	1574	51	1746	56
November	1437	48	1984	66	2215	74
December	1398	45	1163	38	1964	63
TOTAL	**20929**	**57**	**21559**	**59**	**24574**	**68**

* Visitor Center closed 1-6 January 2000 due to illness

The new entrance fees and the improved control system has significantly increased the amount of revenue raised by ACTo, from ¢23,990,280 for 1998 to ¢59,595,400 (approx. US$188,000) for the first ten months of 2000 (Table 14).

Table 14. Paying Visitors to Tortuguero National Park.

	Tortuguero National Park			**Barra del Colorado Wildlife Refuge**	**Tortuguero National Park and Barra del Colorado Wildlife Refuge**
Year	**CR Visitors**	**Foreign Visitors**	**Total Visitors**	**Total Visitors**	**Total Fees Raised**
1996	1,287	7,766	9,053		
1997	2,274	10,757	13,031		
1998	4,284	12,550	16,834	23,256	¢23,990,280
1999	5,767	32,863	38,630	3,650	¢69,641,550
2000	4,780[a]	29,825[a]	34,605[a]	2,261[a]	¢59,595,400[a]

[a] January-October. All data from ACTo.

3.7.2 Capacity of hotels and cabinas

Table 15. Room and bed capacity of the hotels and cabinas in the Tortuguero area.

Hotels/Lodges	**Rooms**	**Beds**	**Cabinas**	**Rooms**	**Beds**
Mawamba	54	137	Ms Junie	12	30
Pachira	48	103	Sabina*	32	80
Tortuga	24	55	Tortuguero	5	15
Caribbean Magic	16	38	Pancana**	-	-
Ilan-Ilan	24	54	Aracari	13	25
El Manati	11	17	Pisulin/Tropical Lodge	5	20
Laguna	51	153	Joruki	6	12
Jungle	43	129	Tu y Yo	3	6
Caribe	9	17	(CCC	7	32)
Total – Hotels	*280*	*703*	*Total – Cabinas*	*83*	*220*
			TOTAL	**363**	**923**

*Data from 1999

**Rooms are now rented out long-term to village residents instead of tourists

Several of the hotels increased their capacity in terms of rooms and beds in 2000, although one hotel slightly decreased its room capacity due to renovation (Table 15).

3.7.3 Turtle walks

From June to October, ACTo issued permits for tour guides to bring a total of 20,824 tourists on turtle walks at night (Table 16). All turtle walks correspond to a total of 2,679 tour guide nights (one tour guide giving one turtle walk is equal to one tour guide night).

Table 16. Tourists paying to go on turtle walks.

Month	Public beach (mile -3/8 to 3 3/8)	Park (mile 3 3/8 to 5)	Total	Tour guide nights
June	1012	563	1575	213
July	4277	1694	5971	744
August	4617	1701	6318	778
September	3511	691	4202	554
October	2494	264	2758	390
TOTAL	**15911**	**4913**	**20824**	**2679**

Data from ACTo.

Tortuguero Development Association charged tour guides an optional ¢200 fee per tourist participating in turtle walks. From this fee the association raised ¢3,190,400 (approx. US$10,064) from 15,952 tourists (data from Tortuguero Development Association). In addition, ¢425,600 (approx. US$1,343) from 2,218 tourists has yet to be paid by 30 tour guides for outstanding fees. All funds are to be used to build a kindergarten (E. Obando pers. comm.).

3.7.4 Artificial lights

Table 17. Artificial lights visible from the beach, Tortuguero river mouth to Mile 5.

Mile	Light source	Beach side	Lagoon side	July	Aug	Sept	Oct
5/8	Tortuga Lodge		X	X			
6/8	Tortuga Lodge		X	X	X	X	X
1	Ilan-Ilan Lodge		X				
1 1/8	House		X	X	X	X	X
1 2/8	Manati Lodge		X	X	X		X
1 3/8	Manati + Laguna Lodge	X	X	X	X		X
1 4/8	Laguna Lodge	X		X		X	X
2	Jungle Lodge		X				
2 2/8	Mawamba Lodge	X			X		X
2 3/8	Mawamba Lodge	X		X	X	X	X
2 4/8	CCC	X			X	X	
2 5/8	CCC	X		X	X	X	X
2 6/8	Houses	X		X	X	X	X
2 7/8	Houses + Street Lights	X		X	X	X	X
3	Houses + Street Lights	X		X	X	X	X
3 1/8	Houses + Street Lights	X		X	X	X	X
3 2/8	Houses + Street Lights	X		X	X	X	X
3 3/8	House	X					
0 to 5	Red light on mast (m2 6/8)	X		X	X	X	X
1/8-6/8, 1 1/8-4 6/8	Street lights (m2 7/8-3 2/8)	X		X	X	X	X

There was little change in the distribution of artificial lights along the northern five miles of beach in 2000 (Table 17). Clearing of beach vegetation along the airstrip (mile 6/8 - 1 3/8), resulted in more lights located behind the airstrip shining onto the beach.

3.7.5 Hatchling orientation

The angular range of hatchling tracks for undisturbed nests (n=72) was $58^{o}\pm28^{o}$. When outliers are excluded the angular range was $47^{o}\pm25^{o}$ (Table 18).

Table 18. Hatchling orientation.

Nests	n	× hatchling tracks ± ST.D.	× angular range ± ST.D.	× angular range minus outlier/s ± ST.D.	Circlers ± ST.D.
Undisturbed	72	61±21	$58^{o}\pm28^{o}$	$47^{o}\pm25^{o}$	0.6±2.7

3.8 Additional Research

Four additional research projects complemented the regular monitoring activities.

3.8.1 Satellite transmitters

After leaving the Tortuguero nesting beach area, we assume that the turtles headed to their feeding grounds. Once reaching the feeding grounds they remained within relatively small areas (Figure 10-17). The two hawksbills headed north to Nicaragua, as did six of the green turtles (Figure 10-15). One green turtle swam to Belize (Figure 16) and one green turtle to Honduras (Figure 17).

At the time of writing this report six transmitters were still sending position data.

3.8.2 Additional nest census by Andrés Ortega, Catalina Reyes, Luciano Segura and Melinda Stockmann

The proportions of green turtle nests deposited in the open, border and vegetation zones were significantly correlated ($p<0.01$) to sand temperature at 70 cm depth in the same zone (Figure 18). The proportion of nests deposited in the open zone decreased as sand temperature increased and the proportion of nests in the border and vegetation zones increased with increased sand temperature.

3.8.3 Study on the effects of temperature on emerging success by Luciano Segura

Sand temperature fluctuated between 26.6ºC and 33.3ºC . There was no difference in emerging success in nests studied during the wet and dry seasons (t-test; $t = -0.13$. $p = 0.9$). No significant correlation was found between mean temperatures at 40 cm and 63 cm and emergence success ($p>0.05$), even when separated by open and border zones. Emerging success was not correlated with nest depth at nest center or bottom ($p>0.05$), even when separated by open and border zones.

3.8.4 Jaguar track survey by Damien Hussy

There seem to exist periods during which the jaguar/s walk/s regularly on the beach, and other times when they are not present on the beach. For example; no tracks were seen 18-23 October, but 7-14 October jaguar tracks were encountered almost daily.

The direction of travel and section of the beach the jaguar/s is/are walking seem to be related. Tracks were commonly heading in a southerly direction close to the village of Tortuguero (mile 3 3/8) and in a northerly direction in the middle of the beach (mile 11-13) and close to Jalova (mile 18). The closest to the village of Tortuguero that jaguar tracks were observed, during the study period, was at mile 3 7/8. The longest travels on the beach observed were 4.5 miles and 4 miles, respectively.

During track surveys of the entire beach, jaguar tracks were often observed close to the park ranger camps which seems to indicate that the jaguar/s was/were not deterred by human presence.

Twice, two different-size sets of jaguar tracks were seen heading in opposite direction the same day.

3.9 Environmental Education Activities

Tour guides and other parties interested in the 1999 program reports were given copies in English or Spanish (depending on preference).

4. DISCUSSION

4.1 Track Surveys

4.1.1 Green turtles

Nesting density was high during the 2000 green turtle season (Figure 1). The vast majority of green turtle nests were deposited 15 June-1 November with few nests laid outside of this time period (Figure 1).

The low nesting density recorded at mile 2-3 may in part be a result of artificial lights shining onto the beach in front of Tortuguero village (Figure 2).

The impressive efforts of the park rangers to control illegal harvest of nesting turtles have had a positive effect in 2000. The very low levels of illegal harvest observed (Figure 3) reflect the efficiency of the park rangers and the beneficial effects of stricter legislation that totally prohibits the fishing of green turtles. It is hoped that the successful protection efforts will be continued during future green turtle nesting seasons.

The large number of jaguar-killed green turtles that were detected during the 2000 green turtle nesting season (Figure 4) may in part be due to increased patrol effort on behalf of sea turtle researchers. University of Florida doctorate student Manjula Tiwari and her assistant Luciano Soares patrolled the beach between the field station (mile 2 5/8) and mile 8 4/8 on a daily basis and recorded many killed turtles that may later have been dragged into the vegetation and missed by the track surveyor. However, the increase in jaguar kills may also reflect a real situation with more green turtles being killed by experienced jaguars. The cubs seen by the track surveyor during the 1997 Green Turtle Program may now have reached maturity and may be killing more green turtles than previously. Increased research into the Tortuguero jaguar population should be encouraged.

4.1.2 Hawksbills

Hawksbill nesting remains at very low levels (Figure 5). All hawksbill nesting coincides with the leatherback and green turtle programs and no additional patrol effort is suggested (Figure 1, 5 and 6).

4.1.3 Leatherbacks

Leatherback nesting peaked early in 2000 (Figure 6). For more details about leatherback nesting 2000, consult Troëng et al. (2000).

4.2 Tagging of Nesting Sea Turtles

4.2.1 Green turtles

It is apparent that the time period for nightly tagging patrols coincides with the period when most green turtle nests are laid at Tortuguero (Figure 1). The low tagging efficiency reflects the large number of nesting turtles rather than inefficiency on behalf of the research assistants. The objective of tagging 1,000 new green turtles was already reached by 26 August (Appendices 1&2). The relatively large number of male green turtles tagged when washed up during copulation also reflects the heavy nesting season with many mating pairs seen from or on the beach during the first two months of the nesting season (early June-early August).

The turtle carrying the Mexican tag was definitely a green turtle (A. Ortega pers.comm.). This only leaves the possibility that the tag number was wrongly recorded in Tortuguero or when the tag was attached in Mexico. The tag returns from Mexico and Panama emphasize the importance of maintaining patrol effort at Tortuguero as it benefits sea turtle research efforts throughout the wider Caribbean.

Probability of tag loss was low at 0.031±0.013 (Table 1a). This reflects the professional work of the research assistants and the field coordinator in ensuring that tags were properly attached to the flippers.

4.2.2 Hawksbills

Only one hawksbill returned with tags from previous years (Appendix 1). Hopefully, increased protection throughout the Caribbean will increase the number of hawksbills returning with old tags in future years.

The idea of hawksbills predominantly nesting in the vegetation does not hold true for the 2000 nesting season at Tortuguero where 2/3 of recorded hawksbill nests were laid in the open zone where there is no shading of the nests.

4.2.3 Leatherbacks

The movement of leatherbacks between nesting beaches in Costa Rica (and beyond) both within and between nesting seasons emphasizes the importance of coordination and

cooperation between conservation programs at these beaches. For further discussion on Tortuguero leatherbacks 2000, consult Troëng et al. (2000).

4.3 Biometric Data Collection

4.3.1 Green turtles

The precision of the carapace measurements was higher for straight than for curved length (Table 3b). However, it is suggested that the practice to collect both measurements is continued in order to make possible the comparison with results from other projects. Also, Tortuguero green turtles may be recaptured at other locations in the Caribbean (or beyond) where only curved carapace measurements are recorded.

4.3.2 Hawksbills

The comments made about curved and straight carapace measurements of Tortuguero green turtles also hold true for Tortuguero hawksbills (Table 5).

4.3.3 Leatherbacks

For further discussion on Tortuguero leatherbacks 2000, consult Troëng et al. (2000).

4.4 Fibropapilloma Assessment

4.4.1 Green turtles

The incidence of fibropapillomas in Tortuguero green turtles appears to be on the rise. This is a cause of concern and continued monitoring of fibropapilloma incidence should be a priority. The front flippers appear to be the body parts most commonly affected by fibropapillomas but it does not appear that this is exclusively correlated to flipper tagging as only two of ten green turtles with fibropapillomas in the front flippers carried tags from previous years.

4.5 Determination of Nest Survivorship and Hatching Success

4.5.1 Green turtles

The high hatching success for undisturbed green turtle nests observed during the 2000 Green Turtle Program is a positive result (Table 6). The same observation was also made for undisturbed leatherback nests laid in 2000 (Troëng et al. 2000). Lower sand temperatures and few flooding events may have contributed to the high hatching and emerging success (Figure 8 and Figure 9). It is also encouraging to see that the number of poached nests was low in 2000 (Table 6 and Figure 7).

4.5.2 Hawksbills

The low hatching and emerging success observed for hawksbill nests are discouraging, in particular in view of the drastic population decline observed in Caribbean hawksbills (Meylan 1999).

4.5.3 Leatherbacks

No leatherback nests were monitored during the 2000 Green Turtle Program. For more information on leatherback hatching success 2000, consult Troëng et al. (2000).

4.6 Physical Data Collection

4.6.1 Rainfall

The green turtle nesting season typically includes a dry period in September (Table 10). The low rainfall will affect the primary sex ratio with nests incubated in September experiencing higher sand temperatures and consequently those nests will produce more female hatchlings.

4.6.2 Air temperature

The dry period is also the period with the highest mean maximum air temperature (Table 11).

4.6.3 Sand temperature

The low rainfall in September no doubts resulted in the highest mean monthly sand temperatures recorded during the 2000 Green Turtle Program (Table 12).

4.6.4 Ground water level

Ground water levels were not sufficiently high to affect green turtle nests in front of the field station until mid-November (Figure 9). The heavy rains in mid-November resulted in high ground water levels that may have flooded nests in front of the field station, close to the high tide line. It is possible that nests deposited further south (Figure 2) may have been affected during earlier flooding events (late June-early July and August) if the beach profile is lower to the south.

4.7 Collection of Human Impact Data

4.7.1 Visitors to Tortuguero

It is encouraging to observe an increase in the number of visitors to the CCC Natural History and Visitors Center (Table 13). December, normally a month of low visitation, was busy in 2000 (A. Castillo and F. Piedra pers. comm.). It is also positive to see that the Tortuguero Conservation Area is raising more fees from tourists visiting the National Park (Table 14).

4.7.2 Capacity of hotels and cabinas

The hotels have a room capacity three times greater than the cabinas in the Tortuguero area (Table 15). It is likely that the hotel profits also vastly exceed the profits made by cabina owners.

4.7.3 Turtle walks

There was no increase in the number of permits for turtle walks in 2000 (Table 16). However, most local tour guides now charge US$10 (instead of US$7) for a turtle walk, which means that the income from turtle walks may have increased considerably in 2000.

4.7.4 Artificial lights

Artificial lights shining onto the beach are increasing in intensity. It is suggested that the development of a plan for shading lights be considered. Such a plan should be developed in cooperation with the development association, hotel owners and the Tortuguero Conservation Area. Less lights in front of Tortuguero village may result in increased green turtle nesting close to the village and would benefit local tour guides as they would have to walk less before encountering nesting turtles.

4.7.5 Hatchling orientation

There does not appear to have been any change in the orientation of green turtle hatchlings (Table 18). However, if artificial lights continue to increase it may affect hatchling orientation and may increase the incidence of hatchling disorientation.

4.8 Additional Research

4.8.1 Satellite transmitters

The Tortuguero satellite tracking project has provided detailed data on hawksbill and green turtle migrations between nesting and feeding grounds (Figure 10-17). The educational aspect of the study has been important and local interest in the project has been great. Maps of the migration paths have been printed and regularly distributed to the Tortuguero school, high school, development association, tour guides, park rangers and other members of the Tortuguero community. The project also received considerable attention in the media, featured in US and Costa Rican TV, and newspapers in Costa Rica, Canada and France. It is suggested that similar projects be implemented during future green turtle and leatherback programs.

4.8.2 Additional nest census by Andrés Ortega, Catalina Reyes, Luciano Segura and Melinda Stockmann

The observation that the proportion of nests in each beach zone is significantly correlated with sand temperature is interesting (Figure 18). It may be that sand moisture is lower at high sand temperatures. This in turn may make it more difficult for green turtles to construct egg chambers in the open zone as egg chambers may collapse in dry sand. This rationale may help explain the observation that the proportion of nests deposited in each beach zone varies by year (Bjorndal and Bolten 1992).

The well-defined wet and dry seasons occurring during the Green Turtle Program may help explain why females encountered nesting 3-4 times in a season often nest in many zones during a season (Bjorndal and Bolten 1992). The green turtles recorded nesting 3-4 times in the same season are likely to have been encountered during both the wet season (when the probability of nesting in the open zone is higher) and during the dry season (when the probabilities of nesting in the border or vegetation zones are higher).

It is suggested that the same study be repeated and that sand moisture be measured to determine if it is the controlling factor for the proportion of nests deposited in each zone.

4.8.3 Study on the effects of temperature on emerging success by Luciano Segura

Sand temperature or nest depth did not appear to be a decisive factor in hatchling emergence. Nests exposed to high temperatures a few days before hatching did not differ in emergence success from nests exposed to lower temperatures.

Other factors such as predation, roots, sand compactness and moisture content, and variations in hatchling fitness may play an important role in a nest's emergence success. Additionally, temperatures in the nest may not have exceeded the suitable range; a greater variation in nest temperature may be necessary to better understand the role of high nest temperatures acting as thermal traps. Finally, nest temperatures were not measured inside the clutch. Increase in temperatures within the clutch, due to metabolic heat, may be a more accurate parameter to measure to study the influence of nest temperatures on hatchling survival and emergence success.

4.8.4 Jaguar track survey by Damien Hussy

Based on the observation of the two distinctly different sets of tracks observed on the beach on the same day, the track observers conclude that at least two jaguars are present in the study area.

4.9 Environmental Education Activities

The most successful environmental education event during the 2000 Green Turtle Program was, without competition, the satellite transmitter attachments and tracking. If at all possible it is suggested that such events be repeated in Tortuguero on an annual basis.

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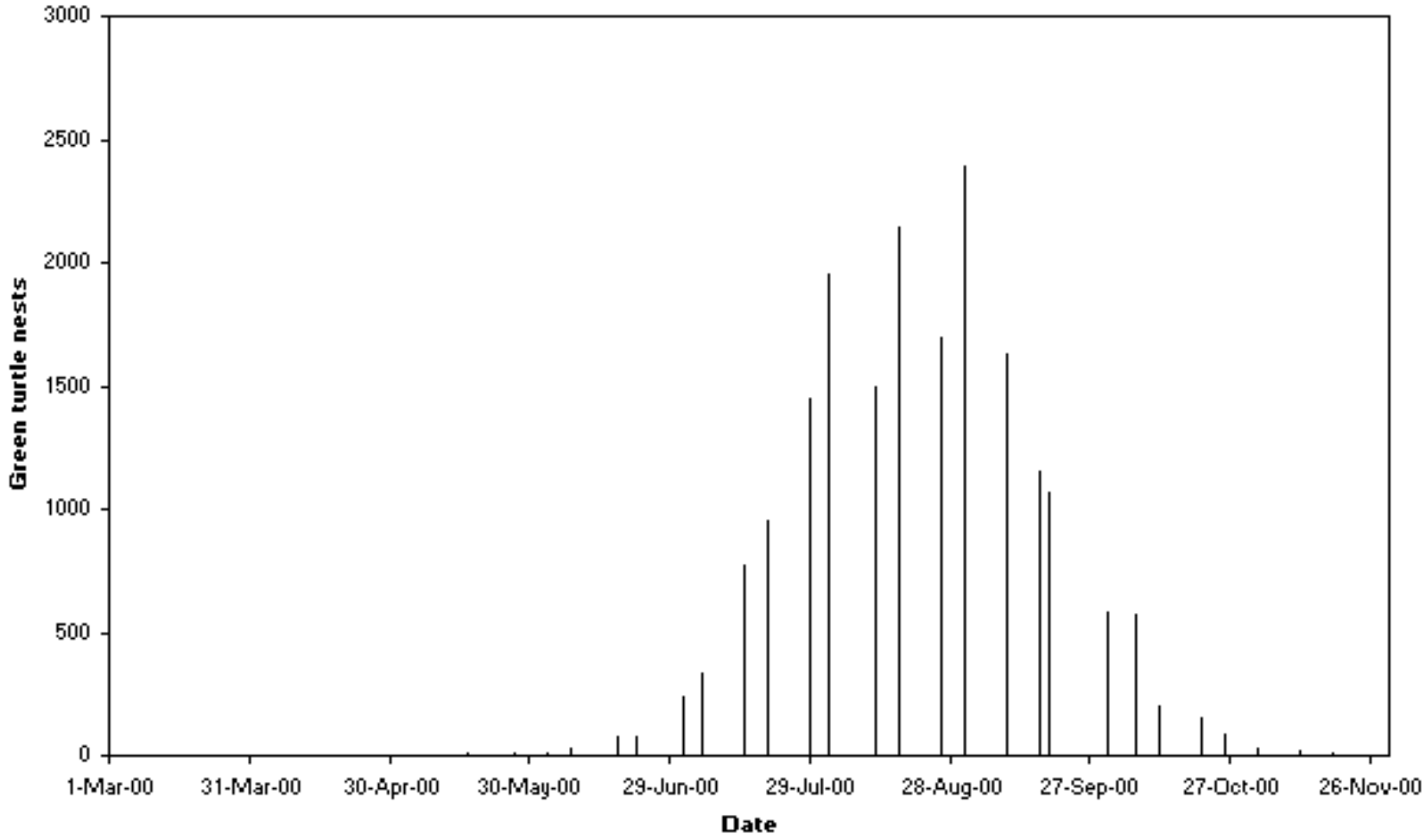
Figure 1. Seasonal distribution of green turtle nesting activity as determined by track surveys from Tortuguero river mouth (mile -3/8) to Jalova lagoon (mile 18).



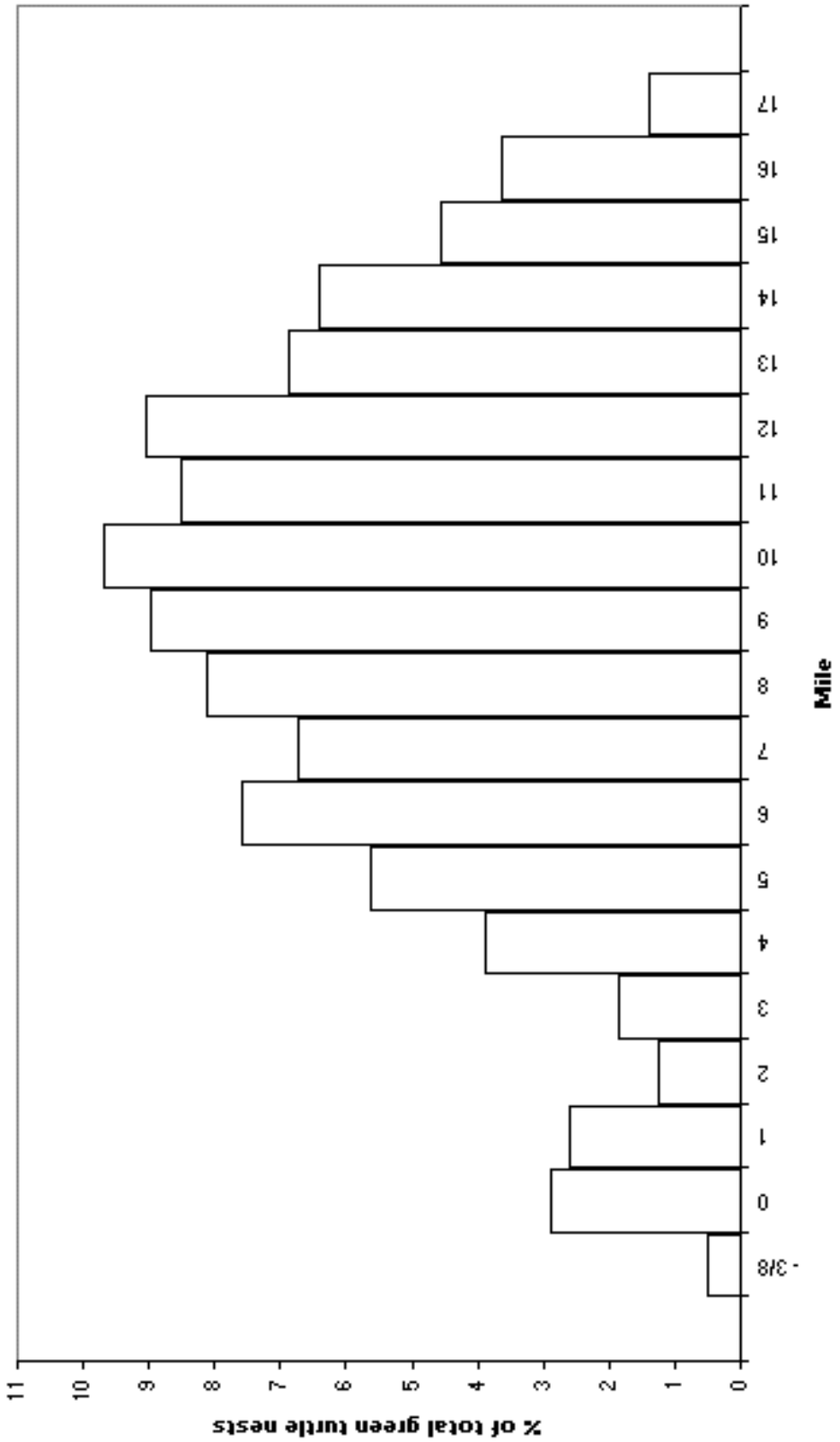


Figure 2. Spatial distribution of green turtle nesting activity as determined by track surveys from Tortuguero river mouth (mile -3/8) to Jalova lagoon (mile 18).

Figure 3. Illegal harvest of green turtles as determined by track surveys from Tortuguero river mouth (mile -3/8) to Jalova lagoon (mile 18).

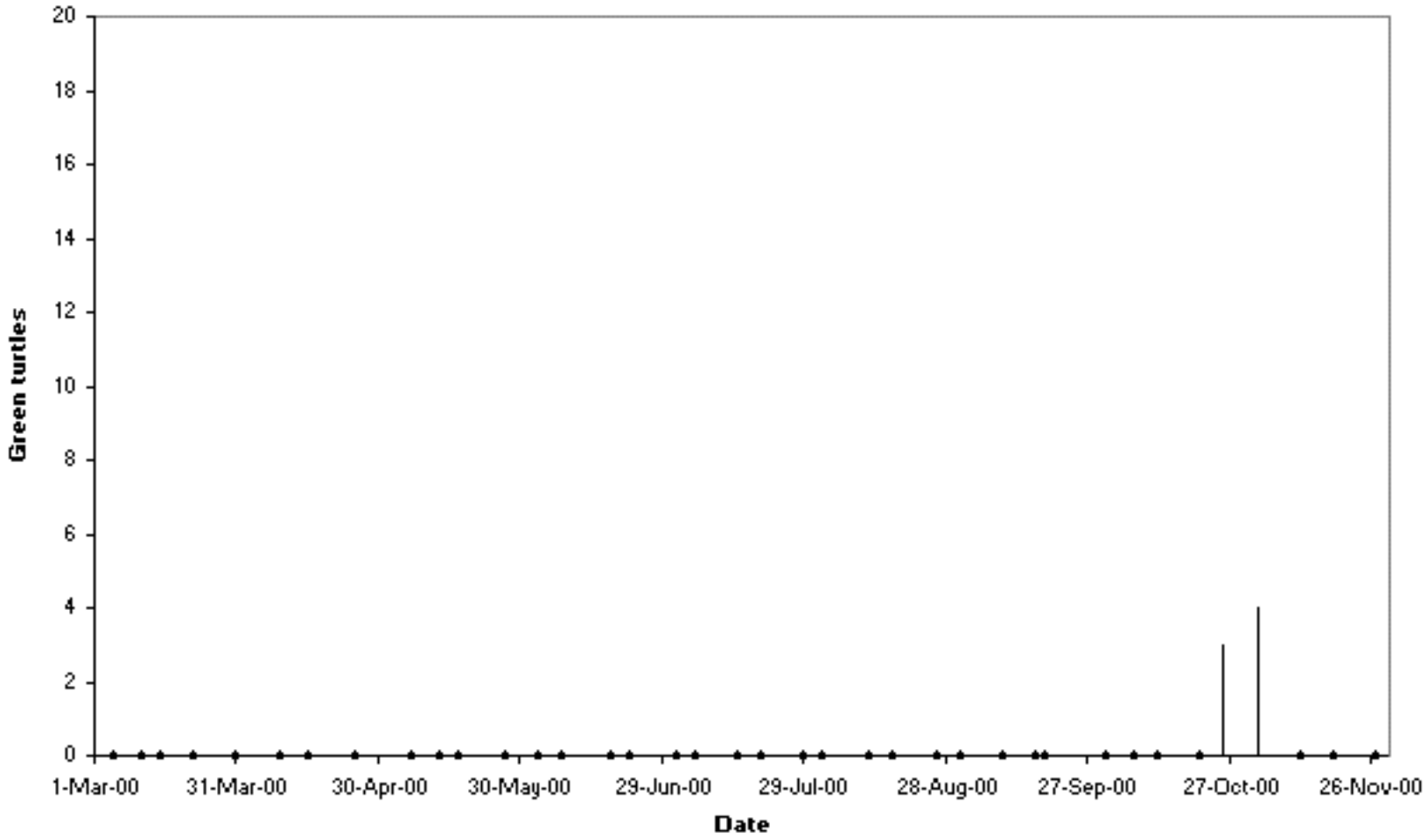


Figure 4. Green turtles killed by jaguars from Tortuguero river mouth (mile -3/8) to Jalova lagoon (mile 18).

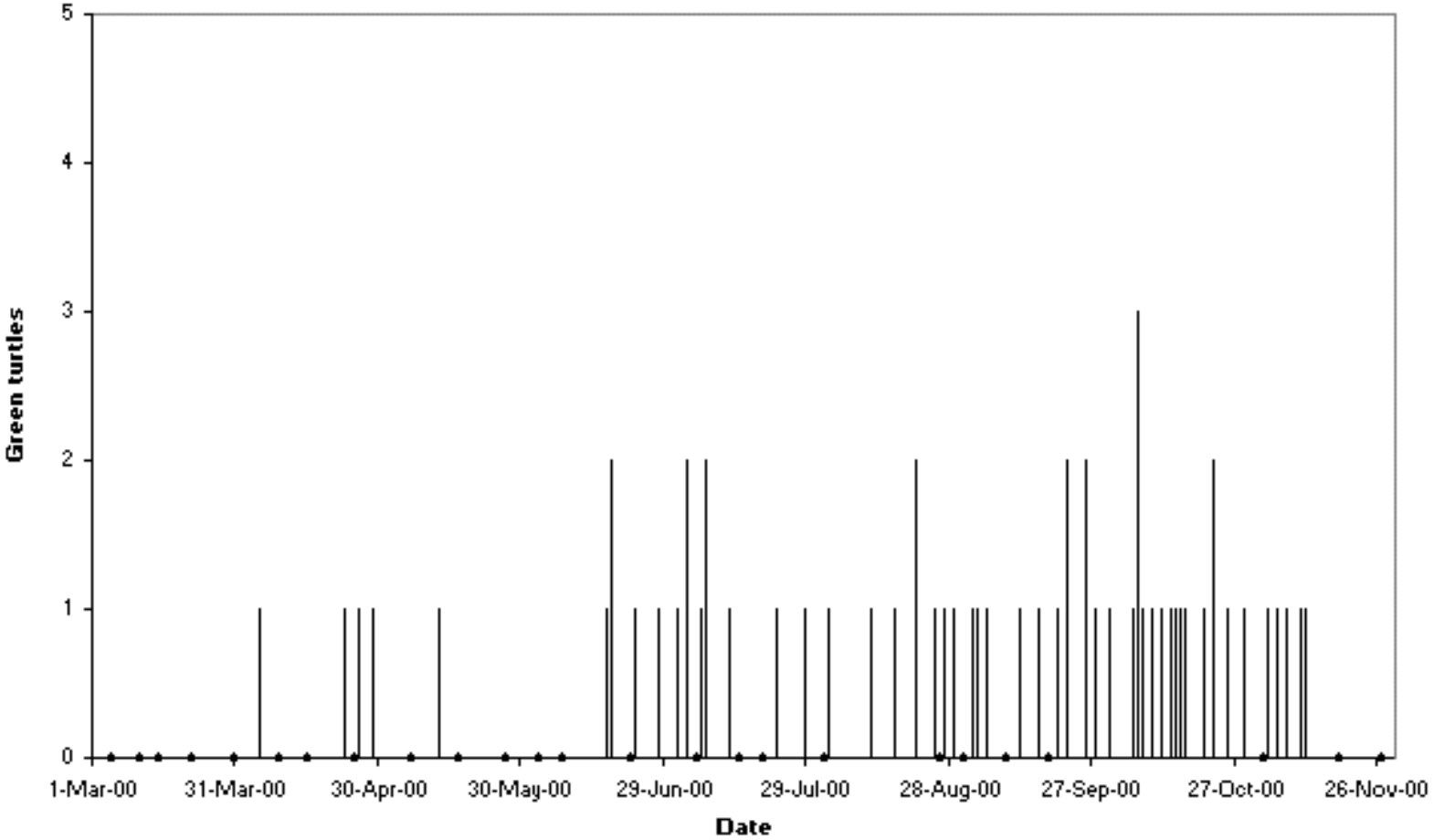


Figure 5. Seasonal distribution of hawksbill nesting activity as determined by track surveys from Tortuguero river mouth (mile -3/8) to Jalova lagoon (mile 18).

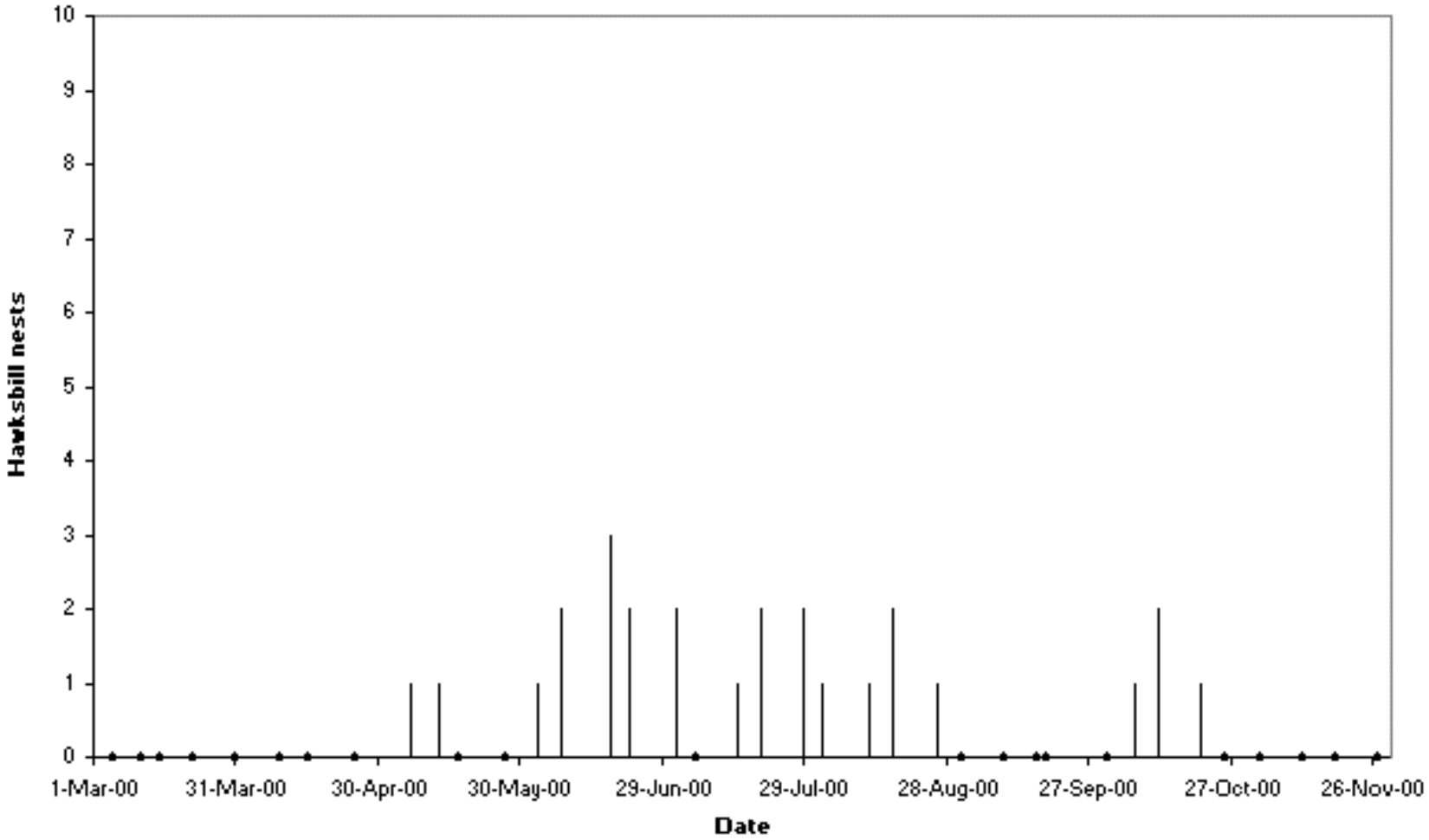
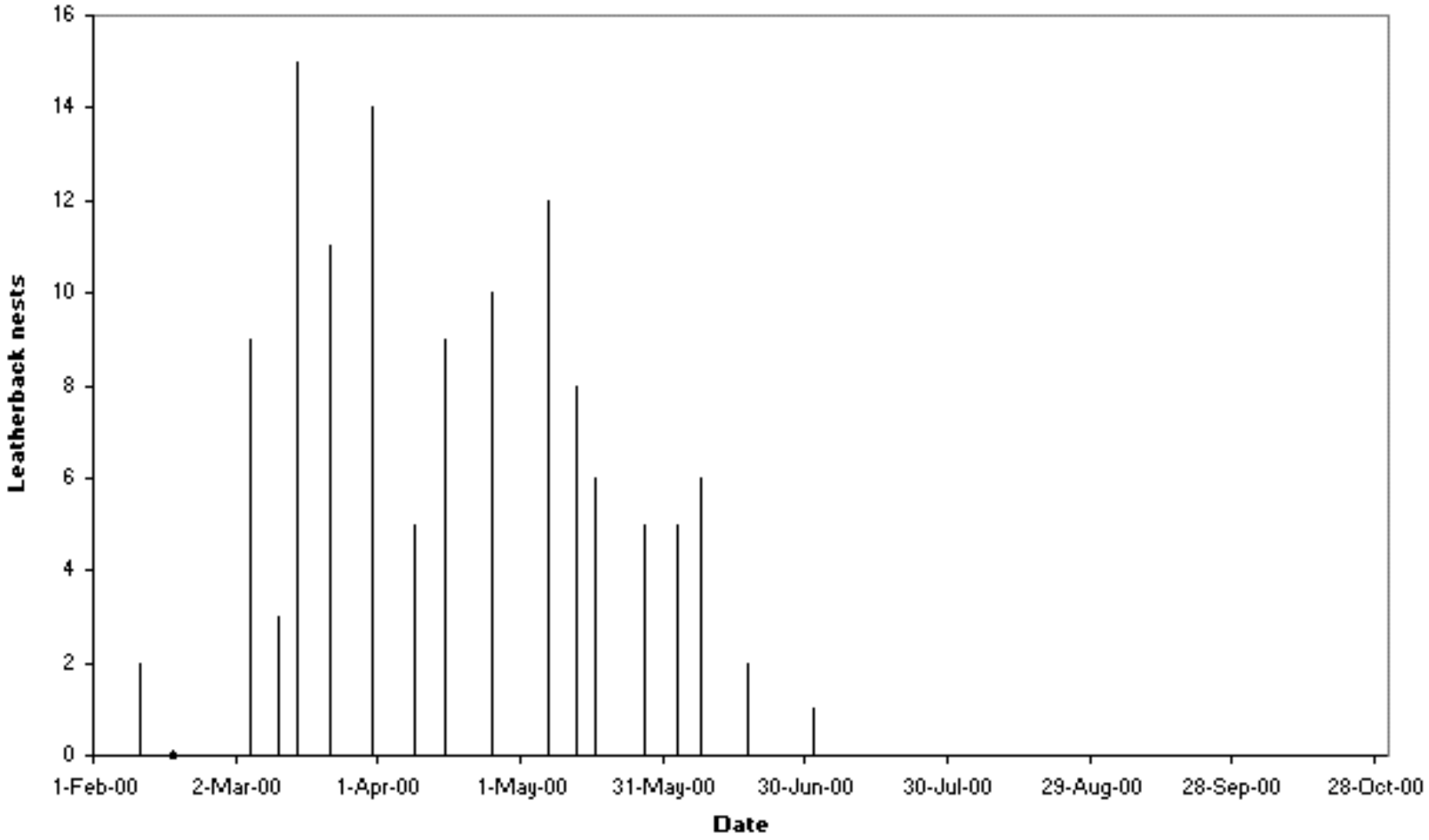


Figure 6. Seasonal distribution of leatherback nesting activity as determined by track surveys from Tortuguero river mouth (mile -3/8) to Jalova lagoon (mile 18).



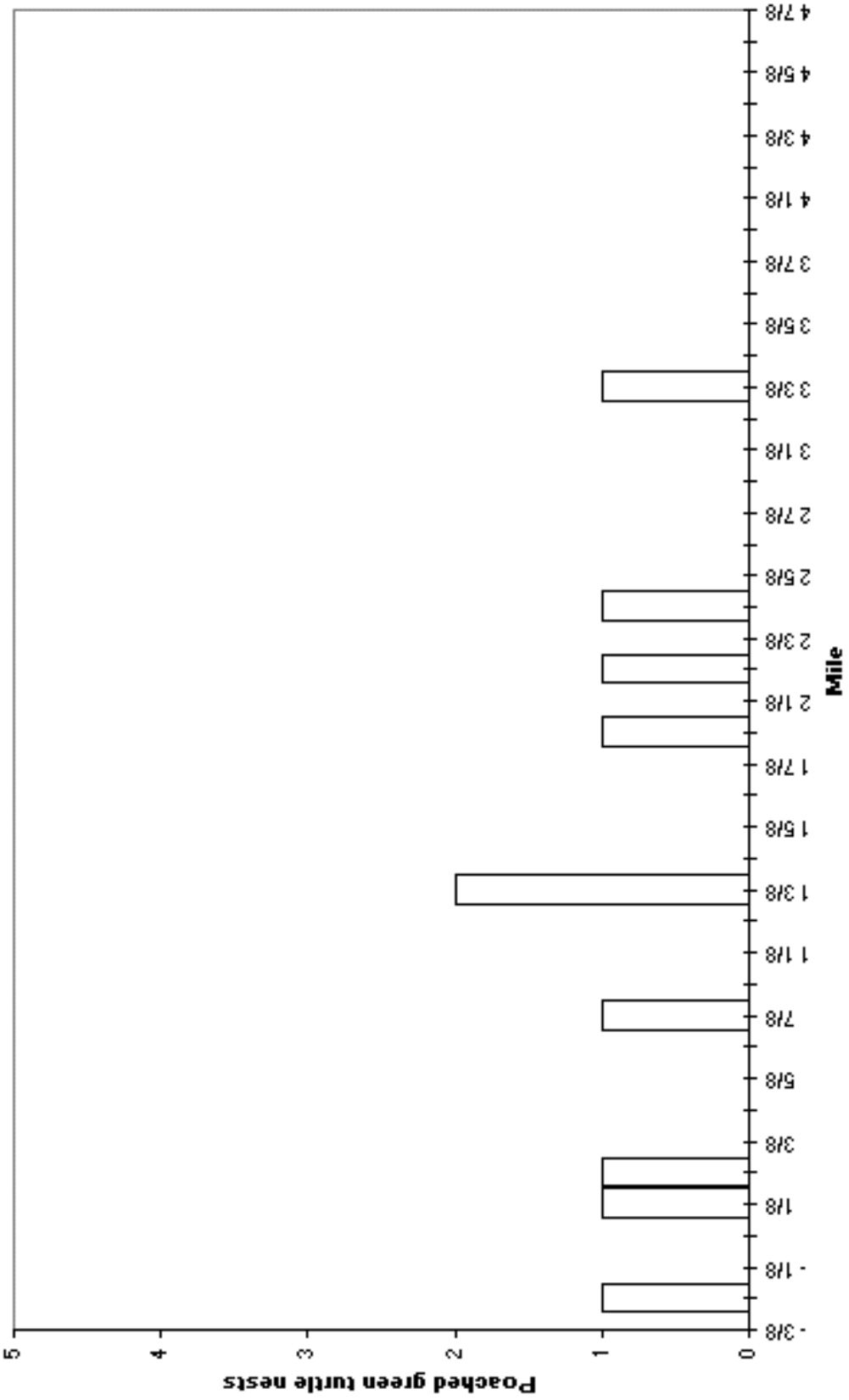


Figure 7. Spatial distribution of marked and subsequently poached nests.

Figure 8. Sand temperatures at 70 cm depth.

Figure 8a. Temperature at 70 cm depth, open zone.

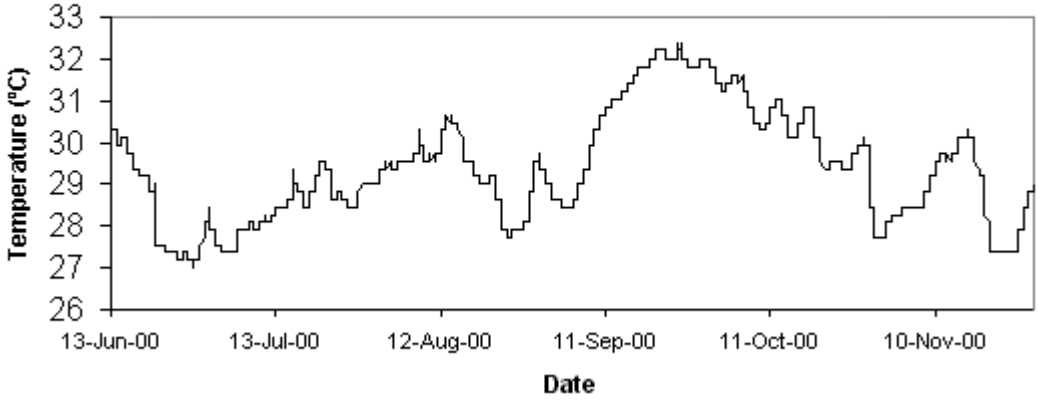


Figure 8b. Temperature at 70 cm depth, border zone.

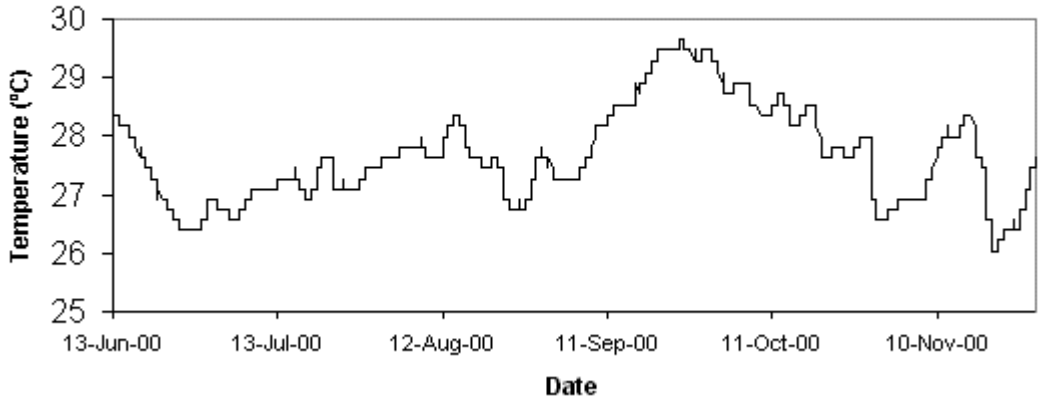


Figure 8c. Temperature at 70 cm depth, vegetation zone.

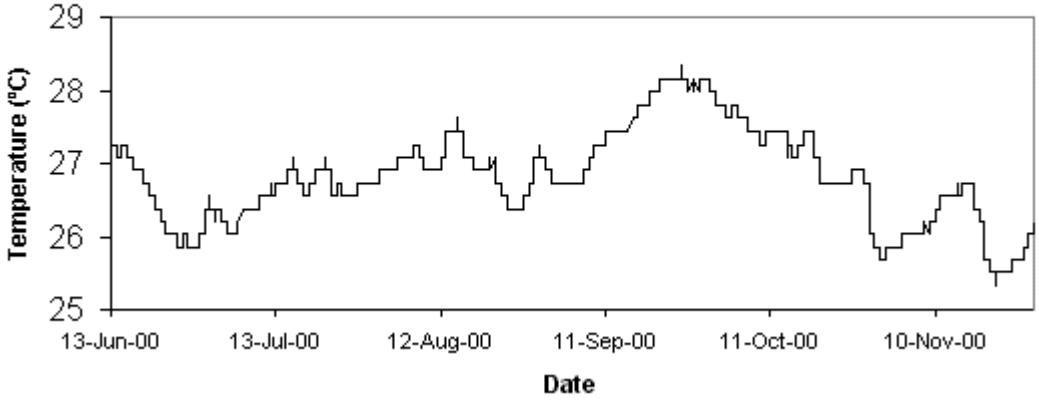


Figure 9. Ground water level.

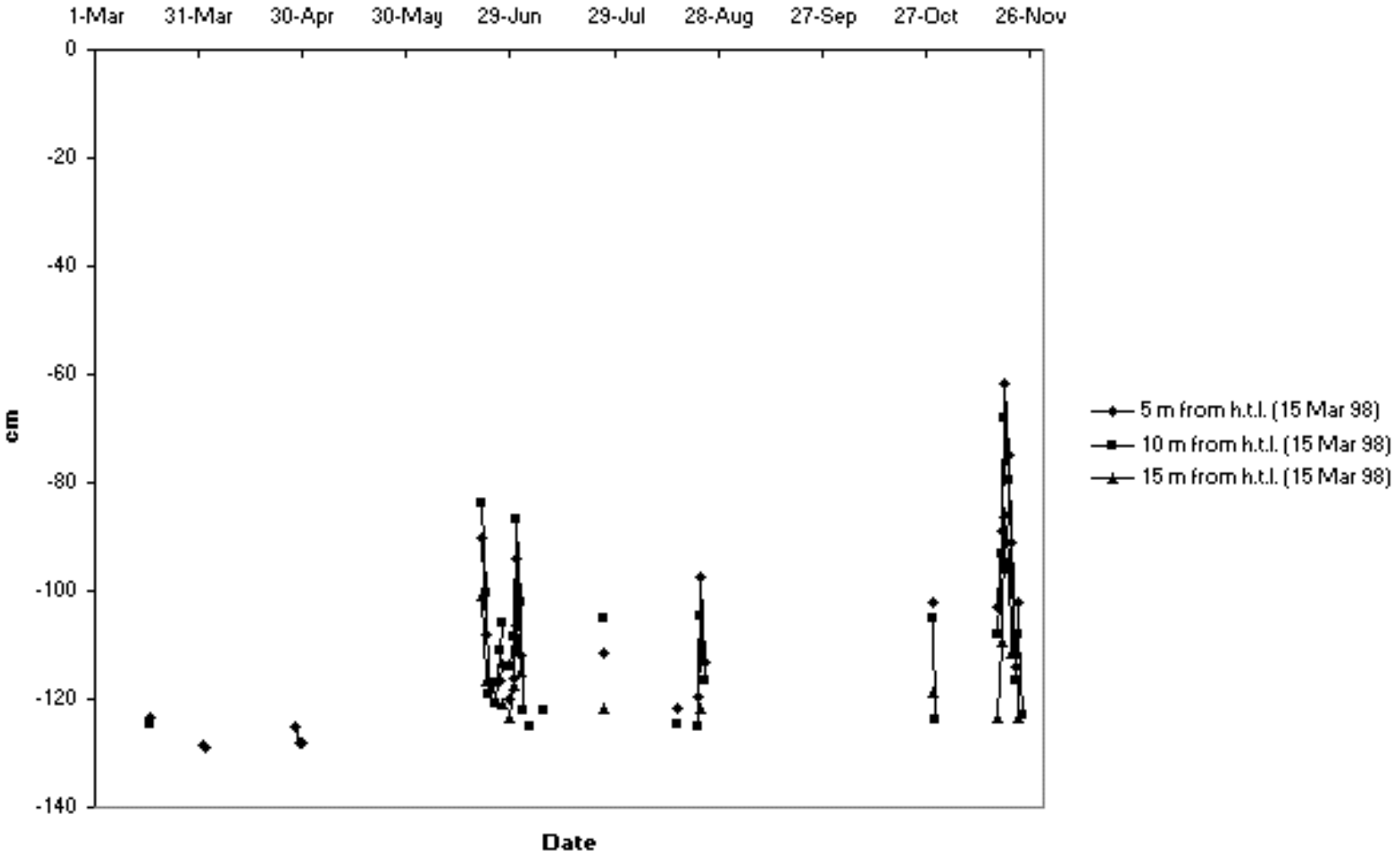


Figure 10. Migration path as determined from satellite tracking of hawksbill Ms. Tomasa.

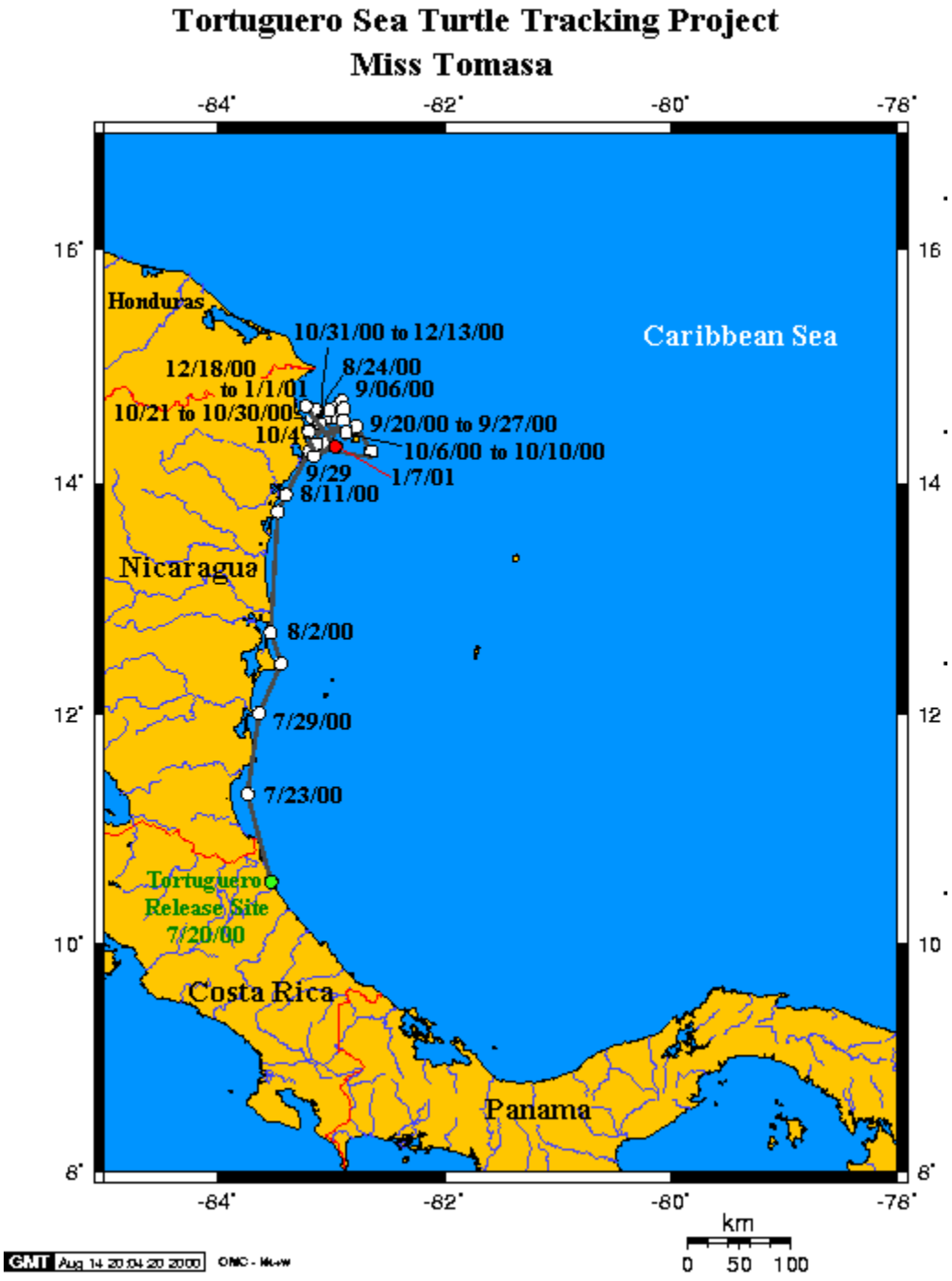


Figure 11. Migration path as determined from satellite tracking of hawksbill Mamoi.

Figure 12. Migration path as determined from satellite tracking of green turtle Mariposita del mar.

Figure 13. Migration path as determined from satellite tracking of green turtle Freed.

Figure 14. Migration path as determined from satellite tracking of green turtle Marea.

Figure 15. Migration path as determined from satellite tracking of green turtle Ms. Junie.

Figure 16. Migration path as determined from satellite tracking of green turtle Zenit.

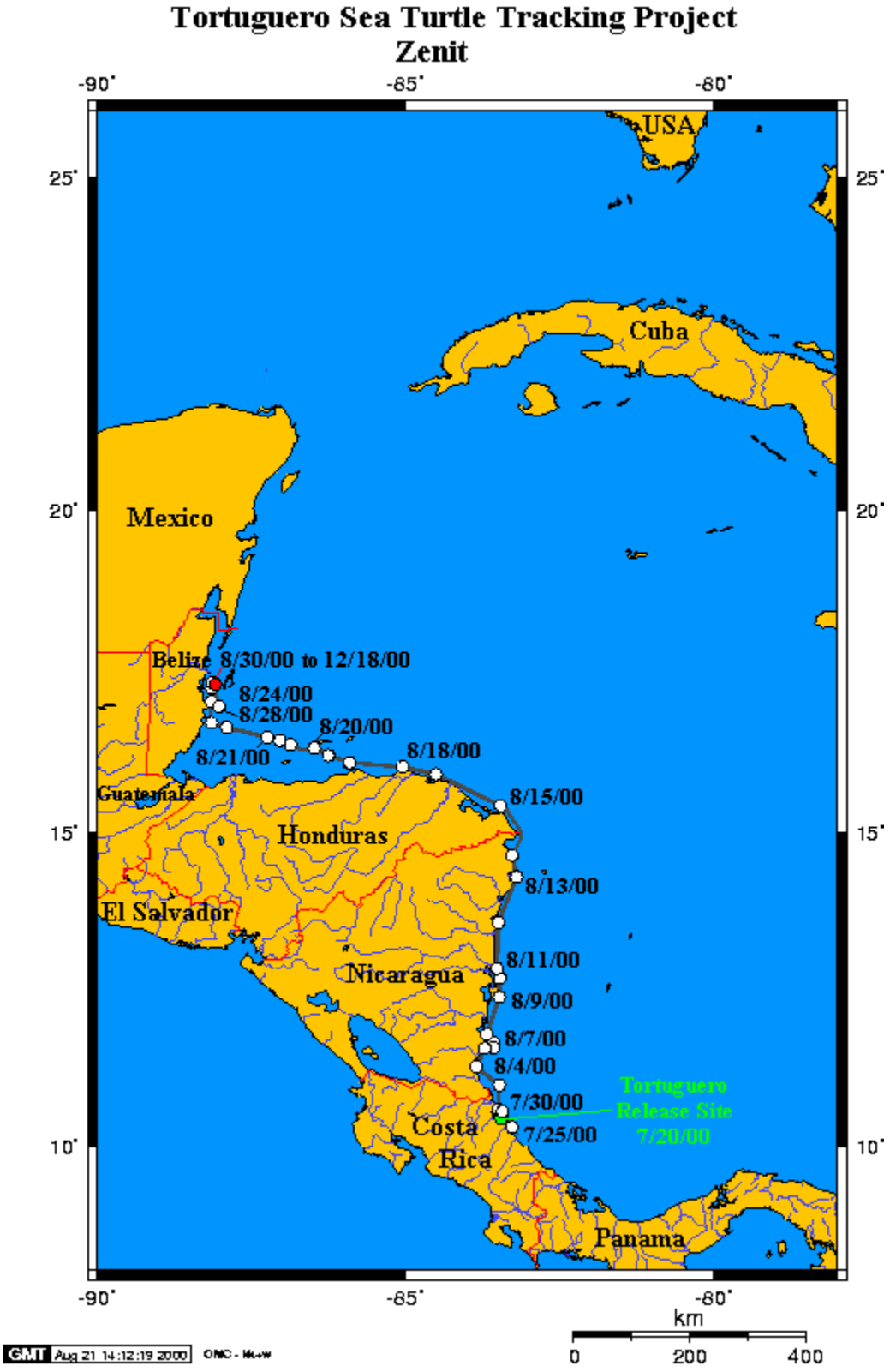


Figure 17. Migration path as determined from satellite tracking of green turtle Esperanza.

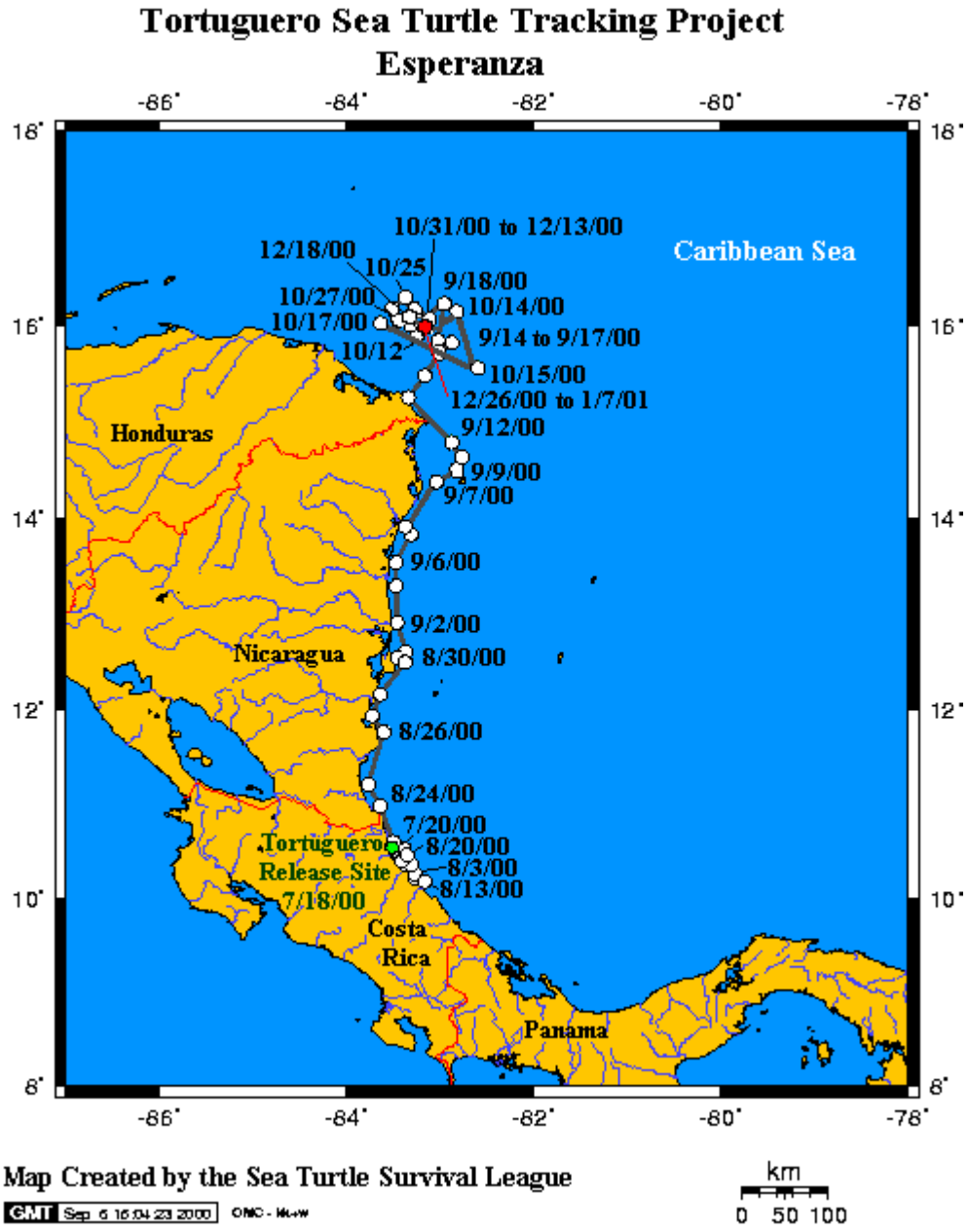


Figure 18. Percentage of nests in each zone and sand temperature at 70 cm.

Figure 18a. Percentage of nests in open zone and sand temperature at 70 cm (open zone).

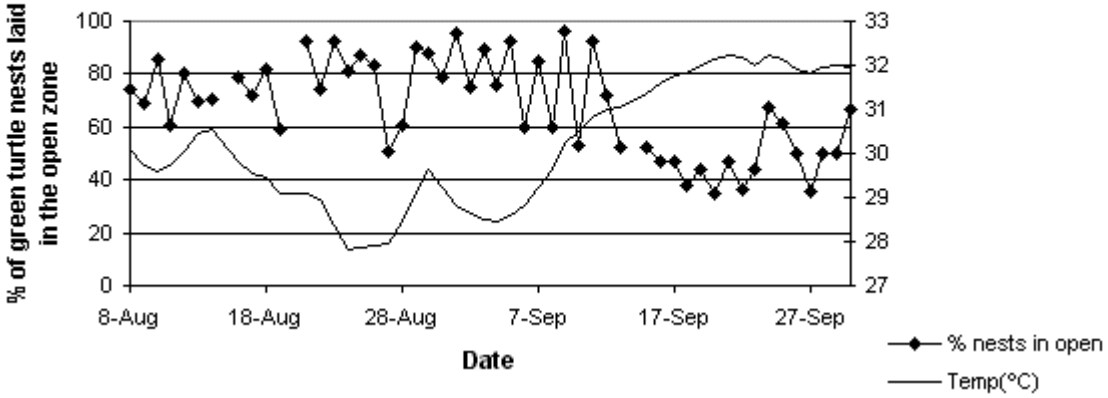


Figure 18b. Percentage of nests in border zone and sand temperature at 70 cm (border zone).

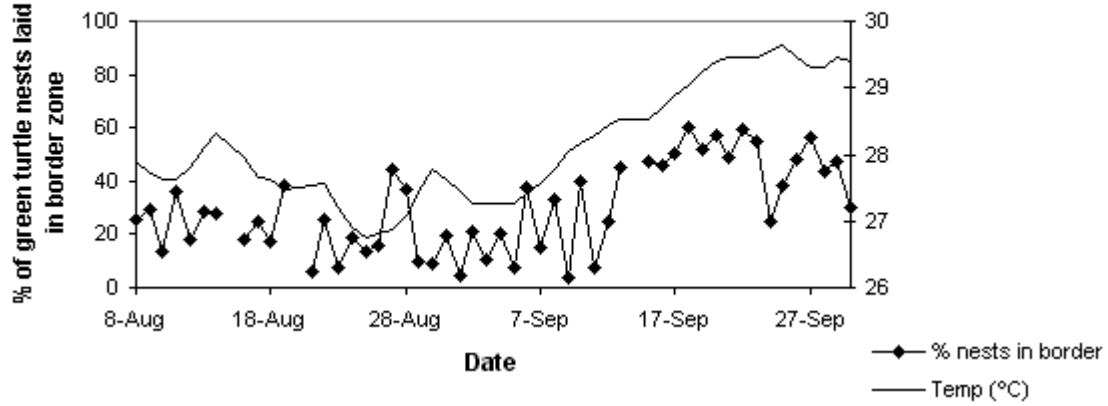
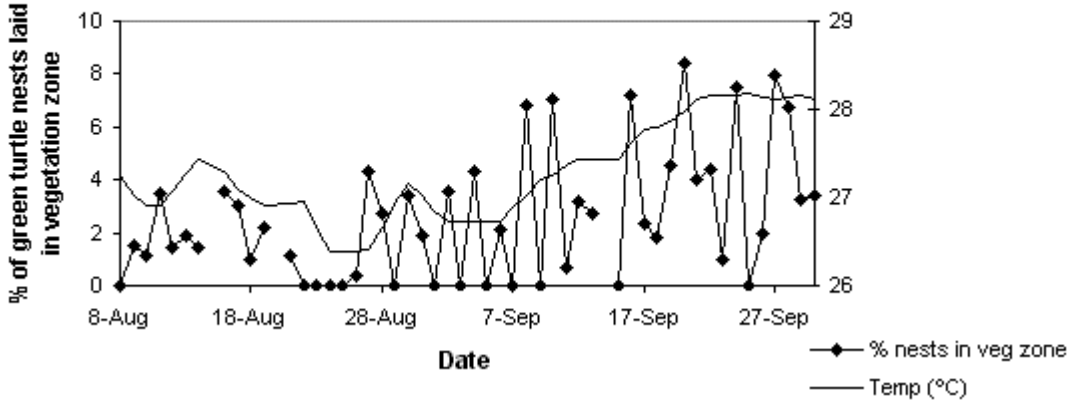


Figure 18c. Percentage of nests in vegetation zone and sand temperature at 70 cm (vegetation zone).



APPENDIX 1. Sea Turtle Encounters During Regular Night Patrols

	Leatherbacks			Green turtles				Hawksbills			
Date	Newly tagged turtles	Previously tagged turtles	Renester	Total	Newly tagged turtles	Previously tagged turtles	Renesters	Total	Newly tagged turtles	Previously tagged turtles	Renesters	Total
09-jun-00				0	1			1				0
10-jun-00				0				1				0
11-jun-00				0	1			2				0
12-jun-00				0				2				0
13-jun-00				0		1		3				0
14-jun-00				0				3				0
15-jun-00				0				3				0
16-jun-00				0		1		4				0
17-jun-00				0	2			6				0
18-jun-00				0	4			10				0
19-jun-00				0		1		11				0
20-jun-00				0				11				0
21-jun-00				0	4	2		17				0
22-jun-00				0	3	1		21				0
23-jun-00				0	1	3	2	27				0
24-jun-00				0	2	3	1	33				0
25-jun-00				0	2	3		38				0
26-jun-00				0		2		40				0
27-jun-00				0	7	2	2	51				0
28-jun-00				0	4	1		56				0
29-jun-00				0	1	2		59				0
30-jun-00				0	2	1		62	1			1
1-jul-00				0	4	2		68	1			2
2-jul-00				0	5	1	2	76				2
3-jul-00				0	7	2	1	86				2
4-jul-00				0	5	3		94				2
5-jul-00				0	4	5	2	105	1			3
6-jul-00				0	14	2	1	122				3
7-jul-00				0	8	4	2	136				3
8-jul-00				0	3	2	5	146				3
9-jul-00				0	11	5	5	167				3
10-jul-00				0	11	1	2	181				3
11-jul-00				0	13	6	2	202				3
12-jul-00				0	13	4	1	220				3
13-jul-00				0	17	9	3	249				3
14-jul-00				0	14	10	3	276				3
15-jul-00				0	18	3	4	301				3
16-jul-00				0	15	5	5	326	1			4
17-jul-00				0	30	9	5	370				4
18-jul-00			1	1	19	8	7	404	1			5
19-jul-00				1	23	8	7	442	1			6
20-jul-00				1	18	1	3	464				6
21-jul-00				1	19	4	7	494				6
22-jul-00				1	18	5	3	520				6
23-jul-00				1	18	3	4	545				6
24-jul-00				1	11	6	2	564				6

25-jul-00		1	12	5	4	585				6
26-jul-00		1	14	9	3	611				6
27-jul-00		1	22	6	4	643				6
28-jul-00		1	11	6	14	674				6
29-jul-00		1	17	4	1	696				6
30-jul-00		1	24	6	3	729				6
31-jul-00		1	20	2	7	758				6
1-aug-00		1	15	4	8	785				6
2-aug-00		1	26	6	6	823				6
3-aug-00		1	12	10	6	851				6
4-aug-00		1	30	3	6	890				6
5-aug-00		1	22	2	7	921				6
6-aug-00		1	19	4	7	951	1			7
7-aug-00		1	22	1	9	983				7
8-aug-00		1	21	9	10	1023				7
9-aug-00		1	41	8	9	1081				7
10-aug-00		1	27	8	8	1124	1			8
11-aug-00		1	22	3	11	1160				8
12-aug-00		1	17	7	12	1196		1		9
13-aug-00		1	16	14	7	1233				9
14-aug-00		1	27	6	9	1275				9
15-aug-00		1	27	4	6	1312				9
16-aug-00		1	18	10	12	1352			1	10
17-aug-00		1	16	6	7	1381				10
18-aug-00		1	22	5	14	1422				10
19-aug-00		1	18	5	10	1455				10
20-aug-00		1	11	6	7	1479				10
21-aug-00		1	18	4	5	1506				10
22-aug-00		1	8	3	7	1524				10
23-aug-00		1	24	7	11	1566				10
24-aug-00		1	14	5	8	1593				10
25-aug-00		1	14	5	11	1623				10
26-aug-00		1	10	1	2	1636				10
27-aug-00		1	16	4	9	1665				10
28-aug-00		1	14	3	7	1689				10
29-aug-00		1	14	4	9	1716				10
30-aug-00		1	12	4	18	1750				10
31-aug-00		1	19	3	7	1779				10
1-sep-00		1	11	7	5	1802				10
2-sep-00		1	13	1	11	1827				10
3-sep-00		1	12	9	11	1859				10
4-sep-00		1	8	3	6	1876				10
5-sep-00		1	20	3	10	1909				10
6-sep-00		1	19	5	10	1943				10
7-sep-00		1	18	2	6	1969				10
8-sep-00		1	16	5	12	2002				10
9-sep-00		1	16	4	8	2030				10
10-sep-00		1	20	5	9	2064				10
11-sep-00		1	1	15	14	2094				10
12-sep-00		1	1	6	13	2114	1			11
13-sep-00		1		4	11	2129				11
14-sep-00		1	3	5	13	2150				11

15-sep-00				1		5	12	2167				11
16-sep-00				1		7	15	2189				11
17-sep-00				1	2	4	10	2205				11
18-sep-00				1	1	6	9	2221				11
19-sep-00				1	2	2	6	2231				11
20-sep-00				1	3	5	6	2245				11
21-sep-00				1	1	2	15	2263				11
22-sep-00				1		3	10	2276				11
23-sep-00				1	1		8	2285				11
24-sep-00				1		6	10	2301				11
25-sep-00				1	1	3	10	2315				11
26-sep-00				1	2	6	7	2330				11
27-sep-00				1	2	5	7	2344				11
28-sep-00				1	1	3	8	2356				11
29-sep-00				1	1	3	14	2374				11
30-sep-00				1	3	2	12	2391				11
1-oct-00				1	3		11	2405				11
2-oct-00				1	1	1	2	2409				11
3-oct-00				1		4	9	2422				11
4-oct-00				1		6	4	2432				11
5-oct-00				1			9	2441				11
6-oct-00				1		6	11	2458				11
7-oct-00				1	1	2	4	2465	1			12
8-oct-00				1		3	15	2483				12
9-oct-00				1		1	9	2493				12
10-oct-00				1	1		1	2495				12
11-oct-00				1		1	7	2503				12
12-oct-00				1		2	8	2513				12
13-oct-00				1	10		6	2529				12
14-oct-00				1				2529				12
15-oct-00				1	2	1	4	2536				12
16-oct-00				1	6		4	2546				12
17-oct-00				1	2	3	2	2553				12
18-oct-00				1				2553				12
19-oct-00				1			8	2561				12
20-oct-00				1			5	2566				12
21-oct-00				1		1	5	2572				12
22-oct-00				1		1	2	2575				12
23-oct-00				1			2	2577				12
24-oct-00				1	1		2	2580				12
25-oct-00				1				2580				12
26-oct-00				1		1		2581				12
27-oct-00				1			1	2582				12
Total	**0**	**1**	**0**	**1**	**1269**	**502**	**811**	**2582**	**10**	**1**	**1**	**12**

APPENDIX 2. Sea Turtle Encounters During Additional Night Patrols

Date	Section	Green Turtles			
		Newly tagged turtles	Previously tagged turtles	Renesters	Total
15-jun-00	Mile 12-15	9			9
16-jun-00	Mile 12-15	8			17
Total		17	0	0	17

APPENDIX 3. Notes and Anecdotal Information on Illegal Harvest

CCC personnel recorded 24 poaching incidents from June to November. Eight incidents involved poaching or attempted poaching of turtle eggs, 16 incidents involved poaching or attempted poaching of a total of 23 nesting turtles. The majority of turtle poaching incidents (9) were in front of town, near the airstrip or near the paths at mile 2. Two turtles were also poached north of the Tortuguero river mouth. Four of the 23 turtles poached were discovered alive and released by CCC research assistants or park guards.