REPORT ON

THE 1999 GREEN TURTLE PROGRAM

AT TORTUGUERO, COSTA RICA

Submitted to
Caribbean Conservation Corporation
and
the Ministry of Environment and Energy of Costa Rica.
22 February 2000

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ACKNOWLEDGMENTS

The 1998 Green Turtle Program was conducted under a research permit from the Ministry of Environment and Energy of Costa Rica detailed in resolution Nº 143-99.

The research assistants Jeff Mangel (USA), Shaleyla Kélez (Peru), Andy Myers (UK), James Kashner (USA), Lynda Bellchambers (Australia), Daniela Vizcaino (Venezuela), Alan Rees (UK), Bendorf Amiteye (Ghana), Edna López (Colombia), Tommy Moorman (USA), Yahaira Rojas (Costa Rica), Lemuel Taylor (Nicaragua), Paula Angeloni (Uruguay), Adner Morales (Honduras), Daniel Quevedo (Honduras), Juan Carlos Melendez (Honduras), Jairo Castro (Costa Rica) 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 1999 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.

Freddy Piedra Pochet, station manager, made everyone feel at home and made sure that all needs for the green turtle program were addressed. Grethel Zamora, visitors center administrator, provided support at all times. William Perez and Errol González provided transport in a timely manner and maintained the field station. Zelmira Williams and Adelina 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. The birdbanders Andy Wilson, Rachel Silverman, Jennifer Soules, Rachel Harden and Kevin Verlander 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. Rubier, Glenn, and Isaias were particularly keen. 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. Enrique Obando 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. Karen Bjorndal and Dr. Anne Meylan kindly provided tag return information. Dr. Bjorndal also provided many useful comments on the draft report.

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 1999 Green Turtle Program represents the second year of implementing the new monitoring protocol.

The objectives of this report are to summarize and discuss the results of the 1999 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 12 June 1999. 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 12 and 15.

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 1999 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 (5:00-5:30 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, false crawl 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 11 June-28 October (except for 14 June). 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.

Tagging teams also patrolled sections between the mile 5 and the mile 15 markers, 1-2, 6-11, 13-20, 23 and 28 September and 30 October (Appendix 2).

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 1999 Green Turtle Program include National Band&Tag Company (NBTC) Inconel #681 tags, no.83005-83025, 83030-83050, 83066-83075, 83078-83079, 83082-85653, 85664-85665, 85676-85679, 85689-85692 and NBTC Monel #49 tags, no. 76212-76213, 76216-76219, 76224, 76243-76245 (Inconel #681 tags, no.83001-83004, 83026-83029, 83051-83065, 83076-83077, 83080-83081 were used during the 1999 Leatherback Program).

2.4.1 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. One green turtle was tagged with Monel#49 tags no.76244-76245.

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.

2.4.2 Hawksbills

Hawksbills (*Eretmochelys imbricata*) were tagged with Inconel #681 tags. Tissue samples were collected from the hawksbills by using a disposable razor blade. The samples were kept in ethanol at the field station until a CITES permit was obtained and the samples could be sent to Dr. Anna Bass at the University of Florida, for analysis. The tagging team always remained with the hawksbill until it had returned to the sea and thoroughly deleted the tracks afterwards.

2.4.3 Leatherbacks

Leatherbacks (*Dermochelys coriacea*) were tagged in the rear flippers using Monel #49 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 of eggs per night as the eggs were being laid. The person counting the eggs wore 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. Tagging teams working south of the mile 5 marker did not measure turtles. 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 supracaudals, 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 laying at the time of encounter.

2.4.3 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 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 when the turtles were laying. The nests were marked with three pieces of flagging. The third piece of flagging 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 tapes.

The distance from the nest to the vegetation and to the latest high tide 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 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, a new shallow hole was dug for them 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 finding many of the marked nests for excavation.

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 egg shells 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 office at Cuatro Esquinas, Tortuguero.

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 that were 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 Environmental Education Activities

Regular environmental education activities were aimed at the Tortuguero school and high school. 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 sea turtle biology slide presentation was given to the staff at the ACTo office in Guápiles.

The fifth international short course in sea turtle biology and conservation was held at the field station 10-24 October 1999. Fourteen participants from Central America attended the course that was taught in Spanish by Dr. Cynthia Lagueux and Ana Barragán.

3. RESULTS

3.1 Track Surveys

3.1.1 Green turtles

Green turtles nested from March to November with the main nesting season extending from July to early November (Figure 1). Peak nesting occurred in mid-September (Figure 1).

Green turtle nesting was densest at mile 8-11 with peak nesting occurring at mile 9 (Figure 2). Nests deposited along the northern five miles of beach, where most nightly tagging takes place represented 8.8% of total green turtle nests (Figure 2).

Illegal harvest of nesting green turtles occurred mainly from April to June, before park rangers set up permanent camps behind the beach inside the national park (Figure 3). Once permanent camps were established in July, illegal harvest was limited. Park rangers patrolling the beach the same night contested the occasion in October when the track surveyor noted ten poached green turtles. Notes and anecdotal information on illegal harvest are summarized in Appendix 3.

Jaguars killed a minimum of 22 green turtles in 1999 (Figure 4). Park rangers, tour guides, Tortuguero villagers and turtle taggers reported seeing tracks from jaguars and several sightings of individual jaguars and a female with cubs were also recorded.

3.1.2 Hawksbills

Hawksbills nested from April to October in very low numbers (Figure 5).

3.1.3 Leatherbacks

The leatherback nesting season extended from March to early July with peak nesting occurring in the second half of May (Figure 6).

3.2 Tagging of Nesting Sea Turtles

3.2.1 Green turtles

A total of 1,041 newly tagged green turtles, 273 carrying tags from previous years and 688 renesters were recorded during the 1999 Green Turtle Program (Appendices 1&2). This only represents a sample of females coming ashore to nest. For green turtles coming ashore between Tortuguero river mouth and the mile 5 marker (nests + false crawls), tagging efficiency varied between 8-100 % with an average of 38 % (st.dev.=24), for nights preceding track surveys (n=17). A green turtle with tags from previous years, nesting at mile 12 4/8 on 17 July was reported by park rangers.

Tag returns from two green turtles tagged outside of Costa Rica were recorded during the Green Turtle Program. One green turtle was encountered nesting at Tortuguero 3 October

1999 and had originally been tagged by Drs. Meylan in Bocas del Toro province, Panama. INRENARE confiscated the turtle from fishermen that had harpooned it off Old Point, Isla de Bastimentos, 20 July 1995. Drs. Meylan were given the turtle and treated, tagged and released it the same day (A. Meylan pers. comm.).

A Tortuguero fisherman caught the second green turtle in a lobster net set close to the Nicaraguan border, in November 1997. The turtle was originally tagged at Great Inagua, southern Bahamas, 26 August 1993 (K. Bjorndal pers. comm.).

A total of 44% of green turtle nests was deposited in the open zone (n=738), 36% in the border zone (n=594) and 20% in the vegetation zone (n=330).

Newly tagged green turtles had evidence of old tag holes or notches in at least one front flipper in 10% of cases (n=102 of 1,033).

The probability of within-season tag loss was 0.058±0.020 (Tables 1a&1b). Within-season tag loss varied with tagger (Table 1a) and month of tagging (Table 1b). Tag loss was highest for green turtles tagged in July and August (Table 1b).

Table 1a. 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	35	0	0±0
RA2	21	0	0±0
RA3	18	0	0±0
RA4	15	0	0±0
RA5	2	0	0±0
RA6	2	0	0±0
RA7	1	0	0±0
RA8	1	0	0±0
RA9	1	0	0±0
RA10	1	0	0±0
RA11	37	2	0.026±0.037
RA12	17	1	0.029±0.057
RA13	47	3	0.031±0.036
RA14	14	1	0.034±0.069
RA15	9	1	0.053±0.105
RA16	34	7	0.093±0.070
RA17	4	1	0.111±0.221
RA18	4	3	0.273±0.303
RA19	8	8	0.333±0.222
RA20	3	3	0.333±0.363
RA21	1	1	0.333±0.629
RA22	1	2	0.500±0.612
RA23	0	1	0.500± N/A
Mixed taggers	2	0	0±0
TOTAL	**278**	**34**	**0.058±0.020**

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	4	0	0±0
July	56	14	0.111±0.059
August	101	17	0.078±0.038
September	105	3	0.014±0.016
October	12	0	0±0
TOTAL	**278**	**34**	**0.058±0.020**

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

3.2.2 Hawksbills

Twelve hawksbills were newly tagged, one hawksbill carrying tags from previous years and one renesting hawksbill (tagged during the 1999 Leatherback Program) were encountered (Appendices 1&2). None of the newly tagged hawksbills had evidence of being previously tagged.

Tissue samples from twelve hawksbill females were exported to Dr. Anna Bass of University of Florida for genetic analysis.

A total of 17% of hawksbill nests were deposited in the open zone (n=2), 58% in the border zone (n=7) and 25% in the vegetation zone (n=3).

3.2.3 Leatherbacks

One leatherback was newly tagged, four with tags from previous years or other projects and one renester were encountered during the Green Turtle Program (Appendix 1).

A total of 83% of leatherback nests were deposited in the open zone (n=5) and 17% in the border zone (n=1). No nests were laid in the vegetation zone.

3.3 Biometric Data Collection

3.3.1 Green turtles

The mean size of nesting green turtles was 104.6 cm CCLmin and 99.0 cm SCLmax (Table 2). Mean clutch size was 110.6 eggs per clutch (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	788	104.6 ± 5.2	745	99.0 ± 4.7	145	110.6 ± 25.2

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	844	0.3 ± 0.2	0-2.4	857	0.2 ± 0.2	0-1.6
Participants	454	0.5 ± 0.4	0-2.5	371	0.3 ± 0.4	0-3.4
TOTAL	**1298**	**0.3 ± 0.3**	**0-2.5**	**1228**	**0.2 ± 0.3**	**0-3.4**

b) during more than one encounter

	CCLmin			SCLmax		
Encounters	**n**	**×±ST.D.**	**Range**	**n**	**×±ST.D.**	**Range**
2	169	1.2±0.7	0.1-4.6	154	0.8±0.7	0-4.5
3	74	1.3±0.6	0.3-3.2	75	1.0±0.5	0.3-2.7
4	35	1.8±0.8	0.7-4.5	29	1.3±0.8	0.5-3.4
5	13	1.9±1.0	0.8-4.2	12	1.2±0.6	0.5-2.6
6	5	2.0±0.9	1.1-3.2	4	1.7±0.7	1.1-2.6

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

3.3.2 Hawksbills

The mean straight carapace length for hawksbills was 83.4 cm (n=13) and the mean clutch size was 156.3 eggs (n=3) (Table 4).

Table 4. Carapace length and clutch size of hawksbills.

Sample	**n**	**× CCLmin ± ST.D. (cm)**	**n**	**× SCLmax ± ST.D. (cm)**	**n**	**× Clutch size ± ST.D. (eggs)**
Females – Tortuguero	13	87.6 ± 5.2	13	83.4 ± 4.1	3	156.3 ± 12.3

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	13	0.5	0.1-1.1	13	0.2	0-0.5

3.3.3 Leatherbacks

Six leatherbacks were measured and no clutches counted (Table 6).

Table 6. Carapace length and clutch size of leatherback turtles.

Sample	**n**	**× CCLmin ± ST.D. (cm)**	**n**	**× Clutch size (eggs+yolkless eggs)**
Females - Tortuguero	6	152.6 ± 6.0	N/A	N/A

3.4 Fibropapilloma Assessment

3.4.1 Green turtles

Nine green turtles with fibropapillomas were encountered, representing 5.4% of carefully examined females (n=167). For eight of the affected turtles the tumors were located on the front flippers, one turtle had a tumor on the rear left flipper. Three of the affected turtles carried tags from previous years, the six newly tagged turtles with tumors did not have old tag holes or notches. Tumors varied in size from 2 cm to 5.2 cm.

3.5 Determination of Nest Survivorship and Hatching Success

Coatis (*Nasua narica*) and domestic dogs (*Canis familiaris*) 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. Yellow-crowned night-herons (*Nyctanassa violacea*) were seen feeding on hatchlings at night. 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 176 green turtle nests was monitored and excavated (Table 7&8). To estimate overall hatching and emerging success, it is assumed that monitored nests contained a mean of 114.6 eggs (this was the mean number of eggs in undisturbed excavated nests). The total number of nests is 179 as three monitored nests were excavated together with other nests (Table 7&8). Hence, overall hatching success was 57.6 % (11,802 empty shells from a total of 20,506 eggs) and emerging success 54.0-55.3 % (11,082-11,346 emerged hatchlings from 20,506 eggs).

Table 7. 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.	55	47	102	58.0	85.9	82.3 - 82.7[b]
Disturbed						
2a. Poached.	24	2	26	14.8	0.4[a]	0.4[a]
2b. Empty egg chamber.	2	1	3	1.7	2.3[a]	2.3[a]
3a. Dug up by dogs after hatching.	1	0	1	0.6	81.4	0 – 81.4[c]
3b. Dug up by mammal after hatching.	0	1	1	0.6	99.1	0 – 99.1[c]
4. Invaded by roots.	1	0	1	0.6	32.3	0
5. Flooded.	1	0	1	0.6	8.0	5.3
6a. Depredated by dogs.	0	1	1	0.6	10.5	10.5
6b. Depredated by mammals.	1	20	21	11.9	11.5	10.1
6c. Depredated by ants.	1	0	1	0.6	0	0
7. Dug up by nesting turtle.	1	3	4	2.3	19.6[a]	19.6[a]
8. Two nests together.	1	2	3	1.7	65.5[a]	61.5[a]
9. Development stopped.	1	4	5	2.8	0	0
10. Hard sand.	3	3	6	3.4	96.2	0 – 95.9[d]
TOTAL	92	84	**176**	100.2	57.6[a]	54.0-55.3[a,b,d]
(11. Excavated by tour guides.	2)					
(12. Undetermined.	3)					

[a]Assuming a mean nest size of ×=114.6 eggs
[b]One undisturbed nest contained many decomposed hatchlings that could not be quantified, hence 2 or all hatchlings died before emerging
[c]Assuming that no or all hatchlings emerged before depredation
[d]Assuming that no or all hatchlings would have emerged naturally from nests with hard sand

A comparison between excavations and egg counts at laying for undisturbed nests (n=63) shows a mean of 0.97±11.5 (range: -51 to 23+ eggs) more eggs counted at laying.

The distance from the sand surface to the top egg after hatchling emergence for undisturbed nests (n=102) varied between 31-79 cm with a mean of 55 cm. The distance from the sand surface to the bottom of the egg chamber for the same nests varied between 45-91 cm with a mean of 71 cm. The incubation period for undisturbed green turtle nests for which emerging was observed (n=47) varied between 51-65 days with a mean of 57 days.

Green turtle nests were poached mainly in the vicinity of the village (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 7). Depredation of nests by mammals (almost exclusively coatis) was common in the national park but rare on the public beach (Table 7). Turtles digging up nests, nests laid close together and stopped development were more common in the national park (Table 7) where nesting density is higher (Figure 2).

Nests deposited in the vegetation zone (n=38) were left undisturbed in 53 % of cases, 51 % of nests in the border zone (n=80) and 71 % of nests in the open zone (n=58) were left undisturbed. Nests depredated by mammals (n=21) were located in the vegetation and border zones in 86 % of cases, and only 14 % were located in the open. Nests in which development stopped were located in the vegetation (n=3) or border (n=2) zones.

Table 8. 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	10043	493	164	218-265	162	123	605	259	0	41
2a	11	0	0	0	1	0	7	0	14	0
2b	8	0	0	0	0	0	4	0	0	0
3a	105	2	0	0	0	0	21	1	1	0
3b	109	0	0	0	0	0	1	0	0	0
4	10	0	10	0	0	1	14	6	0	0
5	6	0	1	1	5	7	43	14	0	2
6a	12	0	0	0	0	0	0	0	0	0
6b	227	19	0	33	2	4	17	117	0	1
6c	0	70	0	0	1	0	1	38	0	0
7	90	1	0	0	0	2	0	169	0	0
8	450	59	11	16	2	0	13	2	0	0
9	0	0	0	0	310	2	306	8	0	0
10	731	1	217	2	3	3	14	8	0	1
ALL	**11802**	**645**	**403**	**270-317**	**486**	**142**	**1046**	**622**	**15**	**45**

For fate, see codes in Table 7.

Table 9. Incidence of albinism, twins and deformed embryos.

	n	**% of total eggs**
Albinos	5	0.024
Twins	3	0.015
Deformed embryos	2	0.010
TOTAL	**10**	**0.049**

Unhatched albinos, twins and seriously deformed embryos accounted for 0.049 % of all green turtle eggs (Table 9).

3.5.2 Hawksbills

Monitored hawksbill nests (n=4) had a mean distance from the sand surface to the top egg of 34 cm (range 28.5-37 cm) and a mean depth from the sand surface to the bottom of the egg chamber of 48 cm (range 36-55 cm).

The fate of monitored hawksbill nests and results from nest excavations are summarized in Table 10. Eggs were counted during laying for two of the monitored hawksbill nests which contained 164 eggs (nest invaded by roots) and 139 eggs (nest undisturbed). At excavation the same nests were estimated to contain only 115 and 129 eggs.

Table 10. 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	2	251	45	110	24	13	5	13	1	328	76.5 %	35.7 %
4	1	26	2	1	1	0	2	35	60	115	22.6 %	20.9 %
10	1	109	1	0	0	2	0	3	0	115	94.8 %	0 % ?

Fate 1=Undisturbed, 4=Invaded by roots and 10=Hard sand stopping hatchlings from emerging

Overall hatching success for monitored hawksbill nests was 69.2 % (386 hatchlings from 558 eggs) and emerging success was 25.3 % (assuming that none of the hatchlings from the nest covered by hard sand would have emerged naturally, hence 141 hatchlings emerged from 558 eggs).

3.5.3 Leatherbacks

No leatherback nests were marked and monitored during the Green Turtle Program.

3.6 Physical Data Collection

3.6.1 Rainfall

Table 11. Rainfall, January-November 1999.

Month	Total rainfall (mm/month)	× rainfall (mm/24hrs)
January	493.2	15.9
February	376.8	13.5
March	189.4	6.1
April	706.3	23.5
May	182.1	5.9
June	511.2	17.0
July	607.0	19.6
August	266.7	8.6
September	130.5	4.4
October	386.5	12.5
November	733.3	24.4

November was the month with the highest rainfall and September the month with the lowest rainfall during the Green Turtle Program (Table 11, Figure 8).

3.6.2 Air temperature

August and September were the months during the Green Turtle Program that had the highest mean maximum air temperature and June was the month with the lowest mean maximum air temperature (Table 12).

Table 12. Air temperature, January-November 1999.

Month	× minimum temp. (ºC) *	× maximum temp. (ºC) *
January	23.6	26.9
February	23.2	27.6
March	23.8	29.4
April	24.7	29.5
May	25.3	30.3
June	24.7	28.9
July	24.1	30.6
August	24.0	31.3
September	24.0	31.2
October	23.6	29.4
November	23.7	29.2

*No data for 11 October or 16 October.

3.6.3 Sand temperature

For the Green Turtle Program, November was the month with lowest mean monthly sand temperature (Table 13, Figure 9). Mean monthly sand temperatures were highest in September (Table 13, Figure 9).

Table 13. Mean monthly sand temperatures.

	Field station			Field station			Field station		
Zone	Open	Open	Open	Bord.	Bord.	Bord.	Veg.	Veg.	Veg.
Depth (cm)		*50*	*70*		*50*	*70*	*30*	*50*	*70*
January, × temp (ºC)	-	27.9	27.7	-	27.2	27.0	25.0	24.9	24.8
February, × temp (ºC)	-	28.8	28.8	-	28.0	27.8	25.4	25.3	25.4
March, × temp (ºC)	(31.8)[a]	30.9	30.6	(30.4)[a]	29.9	29.4	26.5	26.3	26.3
Retrieval depth (cm) 13 March		*56*	*70*		*50*	*70*	*30*	*50*	*70*
Depth (cm) 13 March	*30*	*50*	*70*	*30*	*50*	*70*	*30*	*50*	*70*
April, × temp (ºC)	30.7	30.3	30.3	29.5	29.2	29.0	26.7	26.5	26.5
May, × temp (ºC)	33.0	32.5	32.0	31.4	31.1	30.6	27.8	27.7	27.5
Retrieval depth (cm) 9 June	*37*	*54*	*78*	*29*	*49*	*76*	*32*	*47*	*68*
Depth (cm) 9 June	*30*	*50*	*70*	*30*	*50*	*70*	*30*	*50*	*70*
June, × temp (ºC)	30.3	30.4	30.7	FAIL	29.4	29.4	26.6	26.7	26.9
July, × temp (ºC)	30.1	30.2	30.4	FAIL	29.1	29.1	26.4	26.4	26.6
August, × temp (ºC)	30.4	30.0	29.9	FAIL	28.9	28.7	26.8	26.6	26.7
September, × temp (ºC)	32.7	32.5	32.5	FAIL	30.5	30.4	27.9	27.9	28.0
October, × temp (ºC)	30.6	30.7	31.0	FAIL	28.8	29.0	27.0	27.1	27.4
Retrieval depth (cm) 2 Nov.	*27*	*50*	*66*	*29*	*47*	*66*	*27*	*44*	*67*
Depth (cm) 2 Nov	*30*	*50*	*70*	*N/A*	*50*	*70*	*30*	*50*	*70*
November, × temp (ºC)	28.4	28.5	28.8	-	27.1	27.2	25.9	26.0	26.3
Retrieval depth (cm) 30 Nov.	*34*	*53.5*	*75*	*N/A*	*48.5*	*68.5*	*31.5*	*52*	*72*

[a]Temperature data from 13 March onwards.

Increased shading caused a decrease in sand temperature and also decreased the range of temperatures (Figure 9). For 16 June-18 November the temperature ranged 6.2°C in the open, 5.1°C in the border and only 2.8°C in the vegetation zone (Figure 9).

3.6.4 Ground water level

During the Green Turtle Program, the ground water level was high enough to be noticed in the PVC pipes in the second half of July and in November (Figure 10). At neither of these occasions did the ground water reach a level that could drown green turtle nests located in the border or vegetation zones, in front of the field station.

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 has remained stable at above 20,000 tourists annually for the past three years (Table 14).

Table 14. Visitors to the CCC Natural History and Visitors Center.

	1997		**1998**		**1999**	
Month	**Total**	**× Per Day**	**Total**	**× Per Day**	**Total**	**× Per Day**
January	2695	87	2086	67	2282	74
February	2805	100	2024	72	1967	70
March	2657	86	1812	58	2068	67
April	1553	52	1953	65	1475	49
May	909	29	852	27	1006	32
June	1194	40	1432	48	1093	36
July	2526	81	2555	82	2567	83
August	2498	81	2809	91	2740	88
September	1259	42	1565	52	1640	55
October	1358	44	1006	32	1574	51
November	1468	49	1437	48	1984	66
December*	1401	54	1398	45	1163	38
TOTAL	**22323**	**62**	**20929**	**57**	**21559**	**59**

*No record for 11-15 December 1997

The number of paying visitors to Tortuguero National Park (TNP) increased significantly to 30,620 tourist for the first ten months of 1999 (Table 15). The main cause for this drastic increase is that tourists are now charged the same fee (US$10 per foreign visitor for 4 days/3 nights) for entering TNP and the Barra del Colorado Wildlife Refuge (BCWR). In 1998, the fee was US$6 for TNP and only ¢300 (approx. US$1) for BCWR. Hence, most tourists and guides preferred visiting BCWR (mainly Caño Palma) previous to January 1999.

Table 15. Paying Visitors to Tortuguero National Park.

Year	Tortuguero National Park CR Visitors	Foreign Visitors	Total Visitors	Barra del Colorado Wildlife Refuge Total Visitors	Tortuguero National Park and Barra del Colorado Wildlife Refuge Total Fees Raised
1996	1,287	7,766	9,053		
1997	2,274	10,757	13,031		
1998	2,685	12,313	14,998	23,256	¢23,990,280
1999	4,028[a]	26,592[a]	30,620[a]	2,867[a]	¢50,306,220[b]

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

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 ¢50,306,220 (approx. US$170,530) for the first nine months of 1999 (Table 15).

3.7.2 Capacity of hotels and cabinas

The total room capacity of the hotels and the cabinas increased in 1999, mainly as a result of expansion of the existing hotels in the area (Table 16).

Table 16. Room and bed capacity of the hotels and cabinas in the Tortuguero area.

Hotels/Lodges	Rooms	Beds	Cabinas	Rooms	Beds
Mawamba*	54	151	Ms Junie	12	30
Pachira*	48	94	Sabina	32	80
Tortuga*	24	80	Tortuguero	5	15
Caribbean Magic*	4	12	Pancana	4	10
Ilan-Ilan	26	64	Aracari	12	30
El Manati	8	20	Pisulin/Tropical Lodge	5	20
Laguna*	34	98	Joruki	6	12
Jungle*	50	110	(CCC	7	30)
Caribe	11	30	*Total - Cabinas*	*77*	*215*
Total – Hotels	*259*	*659*	**TOTAL**	**336**	**874**

* Hotel with swimming pool.

3.7.3 Turtle walks

From June to October, ACTo issued permits allowing tour guides to bring a total 20,885 tourists on turtle walks at night (Table 17).

Table 17. Tourists paying to go on turtle walks.

Month	Park (mile 3 3/8 to 5)	Public beach (mile -3/8 to 3 3/8)	Total	Tour guide nights
June	498	938	1436	207
July	1798	3312	5110	677
August	2164	4825	6989	801
September	416	3954	4370	534
October	418	2532	2950	371
TOTAL	**5294**	**15561**	**20885**	**2590**

Data from ACTo.

Tortuguero Development Association charged tour guides an optional ¢150 fee per tourist participating in turtle walks. From this fee the association raised ¢2,359,850 (approx.

US$8000) from 15,761 tourists (data from Tortuguero Development Association). The funds are to be used to complete the multi-use sports court, located next to the village health center (E. Obando pers. comm.).

3.7.4 Artificial lights

There was little change in the distribution of artificial lights along the northern five miles of beach in 1999 (Table 18). However, the construction of a swimming pool at Laguna Lodge (mile 1 4/8) and an additional building at the CCC station (mile 2 5/8) resulted in the lights from these establishments being more visible from the beach. Clearing of beach vegetation just south of the airstrip (mile 1 3/8), in May, resulted in more lights being visible from the beach.

Table 18. Artificial lights visible from the beach, Tortuguero river mouth to Mile 5.

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

3.7.5 Hatchling orientation

The angular range of hatchling tracks for undisturbed nests (n=68) was $56^{o}\pm22^{o}$. When outliers are excluded the angular range was $46^{o}\pm16^{o}$ (Table 19).

Table 19. Hatchling orientation.

Nests	n	× hatchling tracks ± ST.D.	× angular range ± ST.D.	× angular range minus outlier/s ± ST.D.	Circlers ± ST.D.
Undisturbed	68	52±19	$56^{o}\pm22^{o}$	$46^{o}\pm16^{o}$	0.1±0.4

3.8 Environmental Education Activities

The Tortuguero school was visited twice during the Green Turtle Program. The students were divided into groups and the groups were rotated between different activities: slide

show about sea turtle biology, beach walk, drawing turtles and writing stories relating to turtles, exercises/games relating to turtles and visiting the CCC visitors center.

The participants in the short course prepared presentations and visited both the school and the high school. The course participants talked about the sea turtle situation in their home countries and conducted interactive exercises with the students.

Tour guides and other parties interested in the 1998 program reports were given copies in English or Spanish (depending on preference). As a result of the successful tour guide training course in May, many non-tour guides also requested from CCC copies of the reports and information about the biology and conservation of sea turtles.

4. DISCUSSION

4.1 Track Surveys

4.1.1 Green turtles

The green turtle nesting season peaked late in 1999 (Figure 1). This emphasizes the importance of continuing monitoring through the second half of September and October. The variability of the start and end dates of the green turtle nesting season calls for flexibility in the management of protection and tourism. It is appropriate for park rangers to maintain at least one beach camp in the national park from March to the end of green turtle nesting. More beach camps can be established once the main green turtle nesting season begins.

The spatial distribution of green turtle nesting shows that peak nesting is occurring at mile 9 (Figure 2), far south of Tortuguero village. Protection efforts should be strongest along the section of beach where most green turtles nest. The section of beach north of Tortuguero village was surveyed in the afternoon for each track survey. During the 1999 Leatherback Program the number of nests along the northern three miles of beach were underestimated from weekly track surveys (Troëng et al. 2000). It would be interesting to conduct daily track surveys along the northern three miles of beach during the main green turtle nesting season 2000. This would show if green turtle nesting along the northern three miles of beach is underestimated from weekly track surveys.

Illegal harvest was occurring more frequently during March-June when enforcement efforts on the beach in the national park were scarce (Figure 3). Poachers set up several camps behind the beach during these months. The camps were occasionally cleared by park rangers but poaching, mainly of leatherback eggs and nesting green turtles, was rampant (Troëng et al. 2000). Most, if not all poachers using fast boats and advanced equipment come from Limón. Poaching of sea turtles and their eggs therefore represents an illegal resource use with big stakes and outside interests. It has been suggested that appropriate management for such types of coastal resource use is increased enforcement (Cesar et al. 1997). The results from Tortuguero National Park supports this idea as illegal harvest was virtually non-existent once permanent park ranger camps were established in July (Figure

3). The work of ACTo staff during the 1999 green turtle season deserves the highest recommendation.

In February 1999, the Constitutional Court, la Sala IV, ruled that green turtle fishing is no longer permitted on the Caribbean coast of Costa Rica. The change in legislation made the work of the park rangers easier as all caught green turtles are now illegal (E. Chamorro pers. comm.). Since April, CCC has worked together with representatives of the Portete and Cieneguita (Limón) fishermen, government officials and other conservationists in order to identify alternative livelihoods for affected fishermen. A joint proposal for indemnization was prepared and submitted to the government. The proposal has been approved but indemnization money has yet to be paid out.

Jaguars continued to depredate green turtles in 1999 (Figure 4). More green turtles were killed during the dry seasons (March to mid-April, May, mid-August to mid-October) than during the rainy season (Figure 8). Further studies into the area's jaguars are needed to determine if they rely more on green turtles during the dry season, perhaps due to seasonal migrations of other prey species. Park rangers observed a female jaguar with two cubs, feeding on a killed green turtle in early November (Sr. Sandí pers. comm.). In 1997, track surveyor Alonso Rankin spotted a female jaguar with cubs feeding on a green turtle. One could speculate that female jaguars rely on green turtles as an easy food source when their cubs are young.

Sightings of jaguars were reported frequently in 1999, by park rangers, tour guides, villagers and researchers. There are unconfirmed reports that one pregnant jaguar was shot in April and that a male jaguar was killed in October, supposedly for attacking livestock in the Tortuguero area. There is no evidence available to verify these reports.

4.1.2 Hawksbills

Hawksbills have a long nesting season with very low levels of nesting (Figure 5) which makes it difficult to target them with specific monitoring activities. In 1999, hawksbill nesting was occurring during the period in between the Leatherback Program (ended mid-May) and the Green Turtle Program (begun mid-June) (Figure 5). It is likely that more hawksbills would be encountered if the Leatherback Program was extended until the onset of the Green Turtle Program.

4.1.3 Leatherbacks

For discussion of leatherback nesting at Tortuguero, consult Troëng et al. (2000).

4.2 Tagging of Nesting Sea Turtles

4.2.1 Green turtles

It became clear after the first half of the nesting season that the objective of tagging 1,000 new green turtles would not be reached by tagging efforts only in the northern five miles of beach. However, through planning and considerable efforts by the RAs and some program participants in conducting tagging patrols south of the mile 5 marker, the objective was fulfilled. The use of the park service field camps for sleeping and cooking facilities made

this increased effort possible. It is suggested that cooperative efforts of the same type are continued in future program. It not only helps CCC to achieve tagging goals but also increases the exchange between park rangers and RAs.

The two tag returns from other countries emphasizes the importance of the Green Turtle Program in contributing information to many tagging programs throughout the Caribbean and beyond. A decrease in tagging effort would decrease encounters with turtles tagged outside of Costa Rica.

Tag loss varied with person applying the tags and month of tagging (Table 1a&1b). A major reason for the high tag loss in July and August was a pair of non-functional tag pliers. The RC did not identify this until the end of August. Tagging by RAs in September subsequently resulted in lower tag loss. Also, in July and August nesting activity was lower than in September (Figure 1) and RAs often had to tag turtles in front of tour groups (pers. obs.). This increased the pressure on RAs and may also have contributed to higher tag loss. An extended training period in the beginning of the Green Turtle Program would allow the RA to become more confident before having to tag turtles in front of tour groups. It is suggested that several nights are spent practice tagging south of the mile 5 marker, where nesting is denser (Figure 2), before RAs have to conduct patrols without supervision. An increase in RA experience with time may lower tag loss but this does not explain the low tag loss in September and October as all but one RA changed in late August - mid-September.

4.2.2 Hawksbills

The hawksbill turtle carrying tags from a previous year is an encouraging sign that at least some hawksbills survive to nest in more than one season. However, the percentage of remigrating hawksbills is low as the remaining twelve hawksbill females did not carry tags or show evidence of having been previously tagged.

Twelve hawksbill samples were sent to Dr. Anna Bass for analysis. These samples may be insufficient to determine the overall genetic composition of Tortuguero hawksbills. However, continued tissue sampling in future programs will result in an adequate sample size being reached in a couple of years. It is therefore suggested that hawksbill tissue sampling continues to be part of regular monitoring activities.

4.2.3 Leatherbacks

For discussion of leatherback tagging at Tortuguero, consult Troëng et al. (2000).

4.3 Biometric Data Collection

4.3.1 Green turtles

Precision for green turtle carapace length measurements is higher for straight length than for curved length (Table 3a&b). The difference in precision between the measurements is probably due to it being more difficult to define the anterior starting point for the curved than for the straight measurement. It is therefore suggested that SCL max should remain the standard carapace measurement for green turtle monitoring.

4.3.2 Hawksbills

SCL max should also remain as the standard measurement for hawksbills for the same reason as those given for green turtles (see above, Table 5).

4.3.3 Leatherbacks

For discussion of leatherback biometrics, consult Troëng et al. (2000).

4.4 Fibropapilloma Assessment

4.4.1 Green turtles

Fibropapillomas affected 5.4 % of nesting females. Continued monitoring of the incidence of fibropapillomas in future Green Turtle Programs will show if the disease is increasingly affecting nesting females.

4.5 Determination of Nest Survivorship and Hatching Success

4.5.1 Green turtles

Several factors may be responsible for the difference in the mean number of eggs counted at laying and at excavation e.g. eggs may be underestimated at excavations as a result of shredded eggshells or eggs may have been depredated and removed by ghost crabs during incubation.

The presence of park rangers in the national park clearly resulted in low levels of poaching (Figure 7). Poaching was prevalent along the beach section between Tortuguero village and river mouth that was more infrequently patrolled by park rangers. It is apparent that park ranger patrols have a deterring effect on poachers and it is suggested that patrols be increased in future nesting seasons along the affected beach section to prevent poaching. However, if limited park personnel is available it is suggested that efforts are concentrated in the national park where nesting density is higher (Figure 2). Hotel owners could contribute positively by providing funds for additional park rangers to patrol the area between Tortuguero village and river mouth during the main green turtle nesting season.

Coatis were seen depredating green turtle nests throughout the nesting season (pers. obs.) and they may be the major natural mammal predators of turtle eggs in Tortuguero. There are several possible explanations for coatis being observed depredating nests more often than e.g. racoons and tayras. The coati population may be larger than those of other egg predating mammals. The coati olfactory sense is very well developed which may make them more successful egg predators than other mammals (Kaufmann 1983, Sanderson 1983). Also coatis are active diurnally and hence may be seen more often depredating eggs during the day.

It should be noted that more nests were depredated by mammals inside the national park than north of the village (Table 7). The vegetation behind the beach is more extensive and it is likely that more suitable habitat for mammal predators can be found in the national park in comparison with the section north of Tortuguero village. Also, competition from egg poachers was less inside the national park than in front of and north of the village.

From personal observations coatis appeared more common on the beach during 1999 in comparison with the 1998 season. One can speculate that the high abundance of green turtle nests during the 1998 nesting season contributed to a higher survival rate of young coatis resulting in an increased population in 1999. Another personal observation is that coatis appeared to be more commonly seen on the beach during the short dry season in late August-early October. Perhaps coatis and other mammal predators rely more on turtle eggs when other prey is difficult to encounter? These are speculations and further research is needed to better determine the relationship between Tortuguero's sea turtles and mammal predators.

The green turtle nests for which development stopped were located in the vegetation and border zones. It is possible that heavy rainfall combined with low levels of oxygen as a result of a high density of turtle nests and decomposition of organic material caused death by oxygen depletion (Ackerman 1980). Studies into the spatial (distance from sea and vegetation, sand depth) and temporal variation of oxygen concentration in Tortuguero beach should be encouraged.

Nests in the vegetation and border zones were disturbed more frequently than nests deposited in the open zone. However, it is possible that nests in the open are more likely to be flooded or washed out or succumb to high sand temperature during dry periods.

4.5.2 Hawksbills

Hawksbill nests were shallower than green turtle nests due to the smaller size of the flippers and shallow body pit in comparison to green turtles. Emerging success was low for the monitored hawksbill nests (Table 10). One could speculate that the hawksbill's shallow nest, large clutch size, small hatchling size and the tendency of nesting close to or in the vegetation may result in hawksbill nests being more susceptible to oxygen depletion and sand compaction than green turtle nests (Ackerman 1980). More detailed studies of spatial and temporal variation in beach oxygen concentration are needed to test these ideas. There may also be other factors (e.g. grain size and composition) which make hawksbill emerging success lower than green turtle emerging success in Tortuguero.

Hawksbill hatching success is difficult to determine, as the eggshells are smaller and easily break-up. Hence the number of eggshells may be underestimated at excavation. If this is the case then hatching and emerging success for hawksbills are underestimated.

4.5.3 Leatherbacks

For discussion of leatherback nest survivorship and hatching success at Tortuguero, consult Troëng et al. (2000).

4.6 Physical Data Collection

4.6.1 Rainfall

Although seasons are difficult to define in Tortuguero, the rainfall varies considerably between months (Table 11). It is possible that the system of dry and wet seasons affect

plants and the timing of fruiting that in turn may affect food availability higher up in the food chain. Therefore, it is conceivable that terrestrial predators are depending more on nesting turtles and their eggs during periods of dry weather. Another possibility is that terrestrial predators are more dependent on turtle eggs when they raise young. Further research into the biology of Tortuguero's terrestrial turtle and egg predators is needed to verify these hypotheses.

4.6.2 Air temperature

Air and sand temperature are not directly related (Table 12 and 13), e.g. August and September had very similar mean minimum and maximum air temperatures but mean sand temperatures were higher in September. Sand temperature seems to be related to rainfall over a longer time period (Figure 8 and 9).

4.6.3 Sand temperature

The sand temperature increased during periods of low rainfall and decreased during periods of high rainfall (Figure 8 and 9). Increased shading lowered the mean sand temperatures at all depths (Table 13 and Figure 9). The seasonal and spatial variation in sand temperature means that sex ratios for hatchlings may vary depending on the season and nest location.

4.6.4 Ground water level

The ground water level occasionally reached high enough levels to be noted in the PVC pipes in front of the field station (Figure 10). However, only in April, well before the main green turtle nesting season did the water reach levels that may have affected green turtle nests in the border and vegetation zones. One could speculate that heavy rain may be more deleterious to green turtle nests through prohibiting oxygen diffusion into the sand and nest than through flooding from high ground water level. Further research is needed to test this hypothesis.

4.7 Collection of Human Impact Data

4.7.1 Visitors to Tortuguero

The entrance fee increase for the Barra del Colorado Wildlife Refuge (BCWR) and the improved system for collecting park fees which came into place in 1999 clearly improved fundraising for ACTo and changed visitation rates to Tortuguero National Park (TNP) and BCWR (Table 15). Guides, tourists and ACTo personnel have raised concerns that the increase in boat traffic into the smaller canals in TNP may have scared away wildlife from these areas. Further studies are needed to determine the impact of the increased boat traffic.

4.7.2 Capacity of hotels and cabinas

The capacity of hotels and cabinas in Tortuguero continues to increase and the majority of the lodges now have swimming pools (Table 16). There is little control of development in the Tortuguero area and many workers in the tourism industry have expressed their concern that the large-scale tourism brings in many people that have little interest in nature conservation. As the area's tourism in the long term is dependent on Tortuguero's reputation for wildlife and nature viewing it is suggested that the tourism industry impose

self-constraining guidelines to limit uncontrolled development and expanding tourist capacity.

4.7.3 Turtle walks

ACTo issued turtle walk permits for a total of 20,885 tourists but Tortuguero Development Association only received fees for 15,761 tourists (Table 17). There are several reasons for this difference. The fee for the Development Association is optional and some guides (approx. five guides) do not pay the fee for their tourists. Also, not all hotels had paid for all their tourists at the time the data were compiled (hence not all their tourists were included in the Tortuguero Development Association figures). Children do not pay the fee but are included in the total count from ACTo. Another important explanation is that some tourists cancel their tour (e.g. because of bad weather) after the guide has got the permits from ACTo. In such cases the Tortuguero Development Association refunds the fee but the tourists remain in the ACTo statistics (only tourists entering the national park section of the beach have to pay entrance fees to ACTo).

One suggestion to collect more exact numbers on turtle walks would be to charge a compulsory fee to all tourists entering the beach. Part of the fee should go to ACTo and part of the fee to a community organization. It is suggested that the legal aspects of introducing such a fee be investigated. If a fee is introduced, guides should increase the cost of a turtle walk to insure their income.

4.7.4 Artificial lights

Although relatively few artificial lights are visible from the beach (Table 18), it is suggested that existing lights are shaded. Less artificial light on the beach could potentially result in a higher density of nesting females close to the village where nesting density is low (Figure 2). Local tour guides would benefit from a higher nesting density as they would have to walk less to encounter a nesting turtle.

Cutting down of beach vegetation should be strongly discouraged as it makes artificial lights more visible on the beach. Hotel owners benefit from a dark beach in front of their establishment as more turtles may come to nest close to the hotel.

4.7.5 Hatchling orientation

The hatchling orientation data (Table 19) provides a baseline for assessing the effects of increased development of the near beach area. E.g. it makes it possible to test if artificial lights introduced in the future affect hatchling orientation.

4.8 Environmental Education Activities

The Tortuguero community is growing and many new people are arriving in the area. Their knowledge of sea turtles and conservation may be limited and they should be a target group for environmental awareness activities. Also groups are not reached by conventional education activities should be targeted.

It is also suggested that increased efforts be aimed at implementing environmental education activities in Limón and other towns along the Caribbean coast where sea turtle products are consumed.

Educational opportunities in the Tortuguero area are limited. This gives tour guides from central areas of Costa Rica a distinct advantage over local tour guides. CCC can contribute positively by providing local people with training in languages, biology, conservation and presentation skills.

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6. RECOMMENDATIONS

6.1 Track Surveys

⇒ Park rangers should maintain at least one permanent camp at the beach from March until green turtle nesting has finished.

⇒ RAs should conduct daily track surveys along the northern five miles of beach in order to compare results with weekly track surveys.

6.2 Tagging of Nesting Sea Turtles

⇒ RAs using the park rangers' camps increase the exchange between researchers and law enforcers; all such cooperation should be encouraged.

⇒ RAs should be given extensive tagging training south of the mile 5 marker before they have to conduct night patrols unsupervised.

⇒ If tagging patrols are extended to cover the time period between the current Leatherback and Green Turtle Programs, more hawksbills may be encountered.

⇒ Collection of tissue samples from hawksbills for DNA analysis should be part of regular monitoring.

6.3 Biometric Data Collection

⇒ SCLmax should remain the standard carapace measurement for green turtles and hawksbills.

6.4 Fibropapilloma Assessment

⇒ Continued monitoring of fibropapilloma incidence will show if the frequency of affected females is increasing.

6.5 Determination of Nest Survivorship and Hatching Success

⇒ Studies of temporal variation in plant production and animal feeding habits in Tortuguero National Park should be encouraged.

⇒ Studies of the biology and population dynamics of mammalian egg predators should be encouraged.

⇒ Studies of the spatial (depth, distance from vegetation and sea) and temporal variation in sand oxygen concentration should be encouraged.

6.6 Physical Data Collection

⇒ Studies aimed at assessing the effects of variation in rainfall on Tortuguero's flora and fauna should be encouraged.

⇒ Studies aimed at determining the effect of heavy rainfall on egg survivorship should be encouraged.

6.7 Collection of Human Impact Data

⇒ Studies of the impact of boat traffic in the Tortuguero canals should be encouraged.
⇒ Hotel owners should impose self-constraints on uncontrolled development and tourist capacity.
⇒ It is suggested that tourists going on turtle walks pay a fee to ACTo and the Tortuguero community. If this is done it is suggested that tour guides increase the cost of a turtle walk in order to maintain their income.

6.8 Environmental Education Activities

⇒ Environmental education efforts should be aimed at recently arrived villagers, groups not reached by traditional awareness activities, and communities along the Caribbean coast.
⇒ CCC should increase training opportunities for local people in Tortuguero.

6.9 Other Recommendations

⇒ If personnel are available, more ranger patrols should be carried out between Tortuguero village and river mouth.
⇒ Hotel owners can contribute positively by providing funds for additional beach patrols between Tortuguero village and river mouth.
⇒ Cooperation with the Portete and Cieneguita Fishermen Association should be continued and if possible expanded.

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

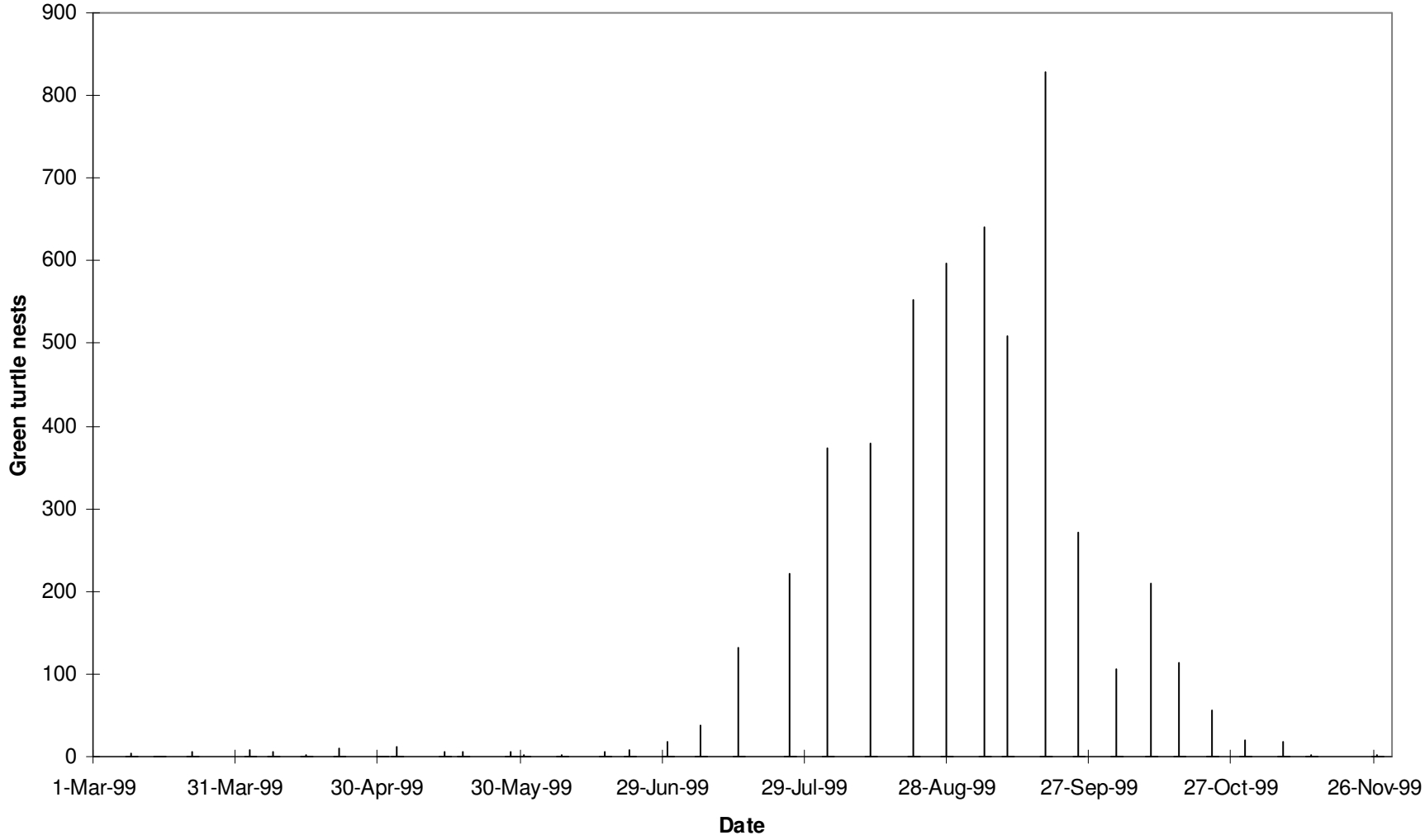


Figure 2. Spatial distribution of green turtle nesting activity as determined by track surveys from Tortuguero rivermouth (mile -3/8) to Jalova lagoon (mile 18).

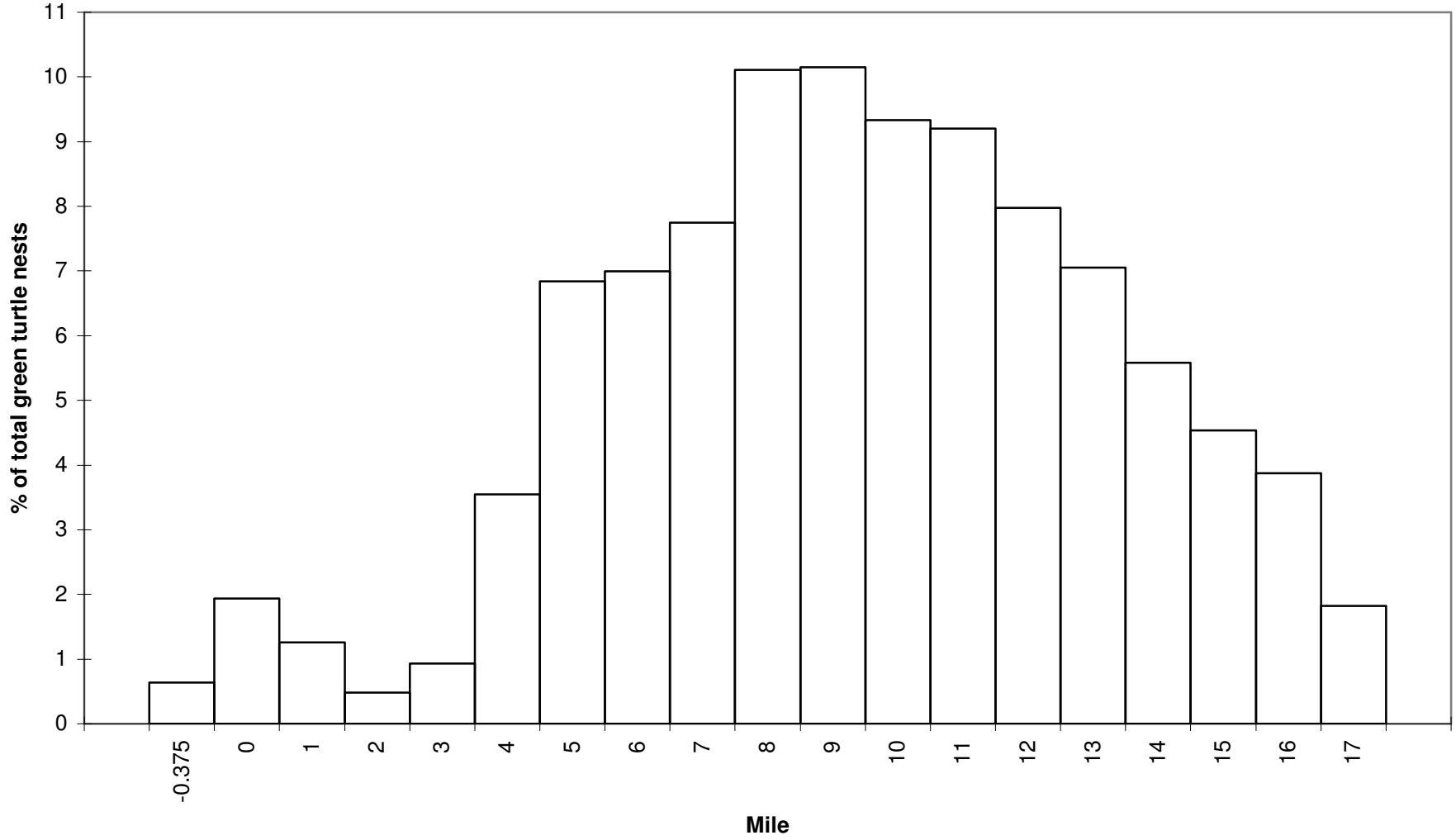


Figure 3. Illegal harvest of green turtles as determined by track surveys from Tortuguero rivermouth (mile -3/8) to Jalova lagoon (mile 18).

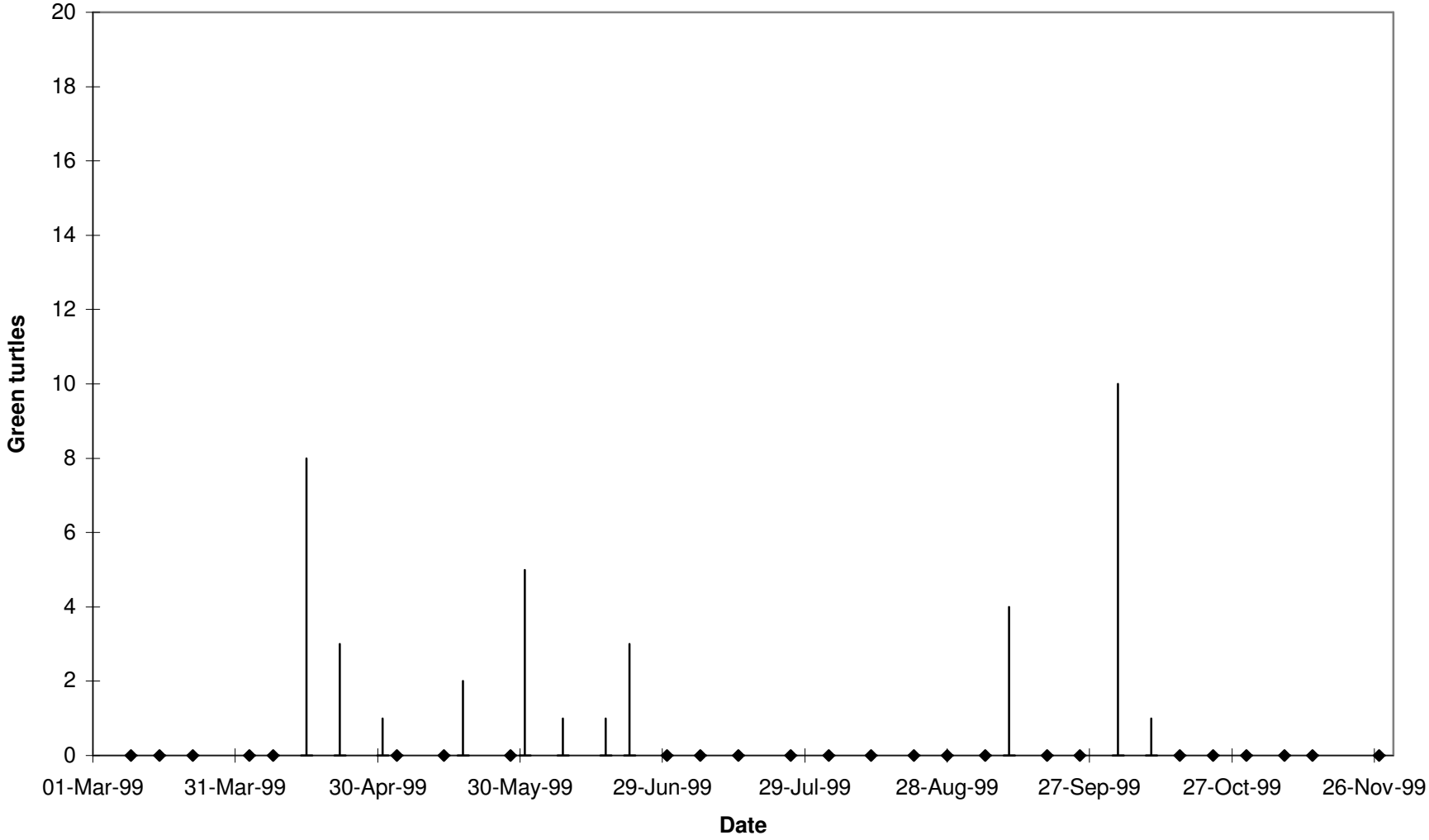


Figure 4. Green turtles killed by jaguars as determined by track surveys from Tortuguero rivermouth (mile -3/8) to Jalova lagoon (mile 18).

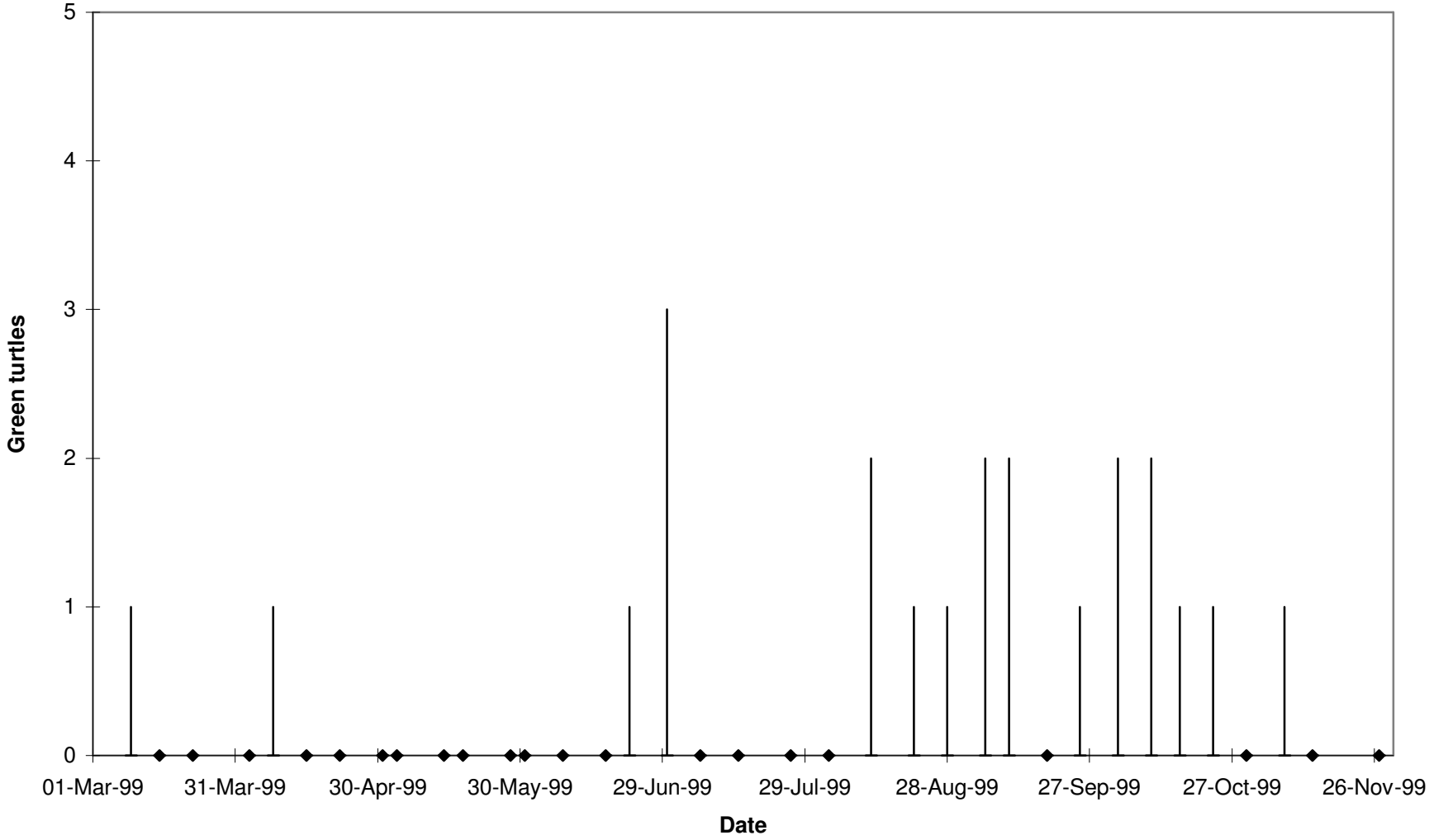


Figure 5. Seasonal distribution of hawksbill nesting activity as determined by track surveys from Tortuguero rivermouth (mile -3/8) to Jalova lagoon (mile 18).

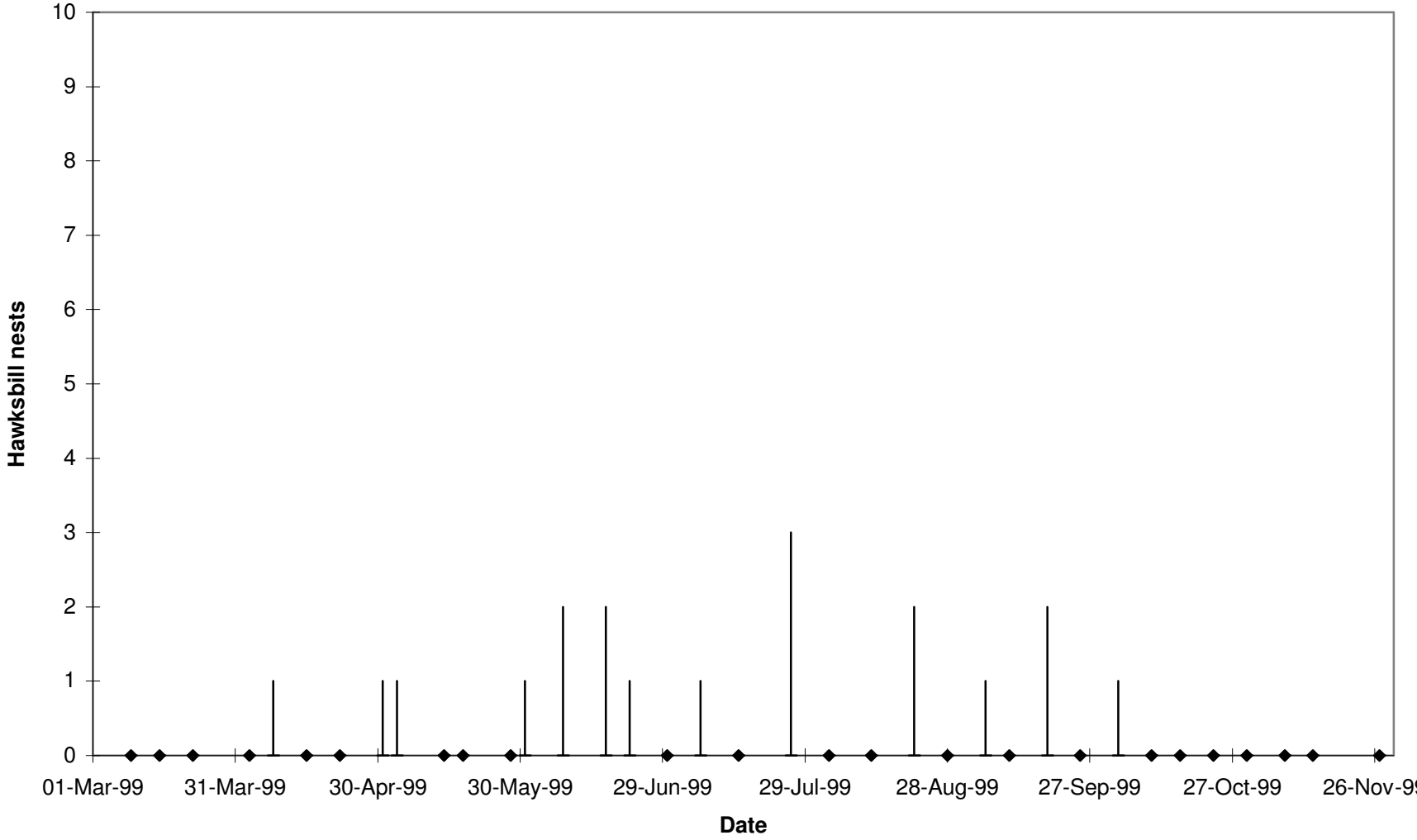


Figure 6. Seasonal distribution of leatherback nesting activity as determined by track surveys from Tortuguero rivermouth (mile -3/8) to Jalova lagoon (mile 18).

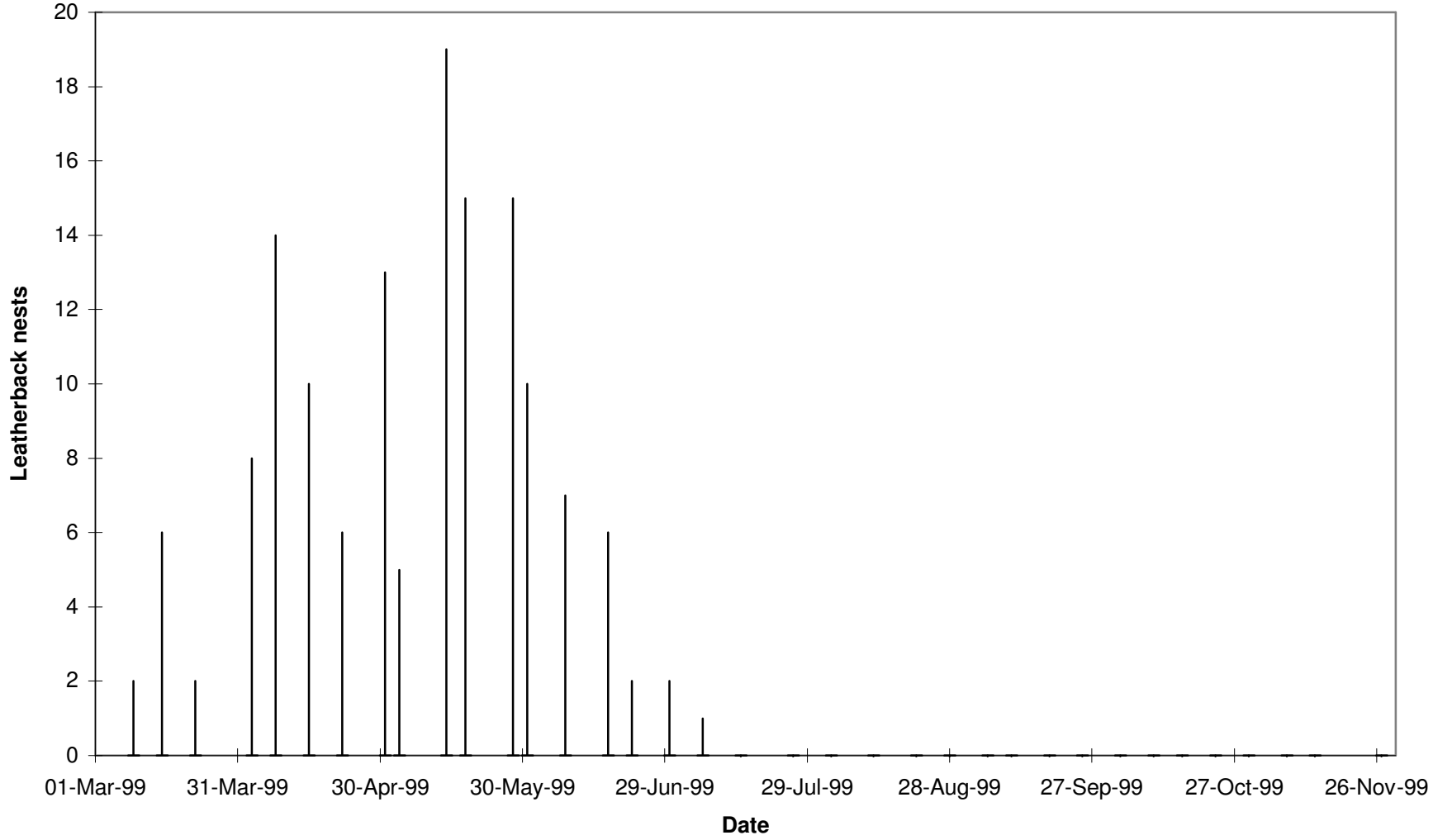


Figure 7. Spatial distribution of marked and subsequently poached nests.

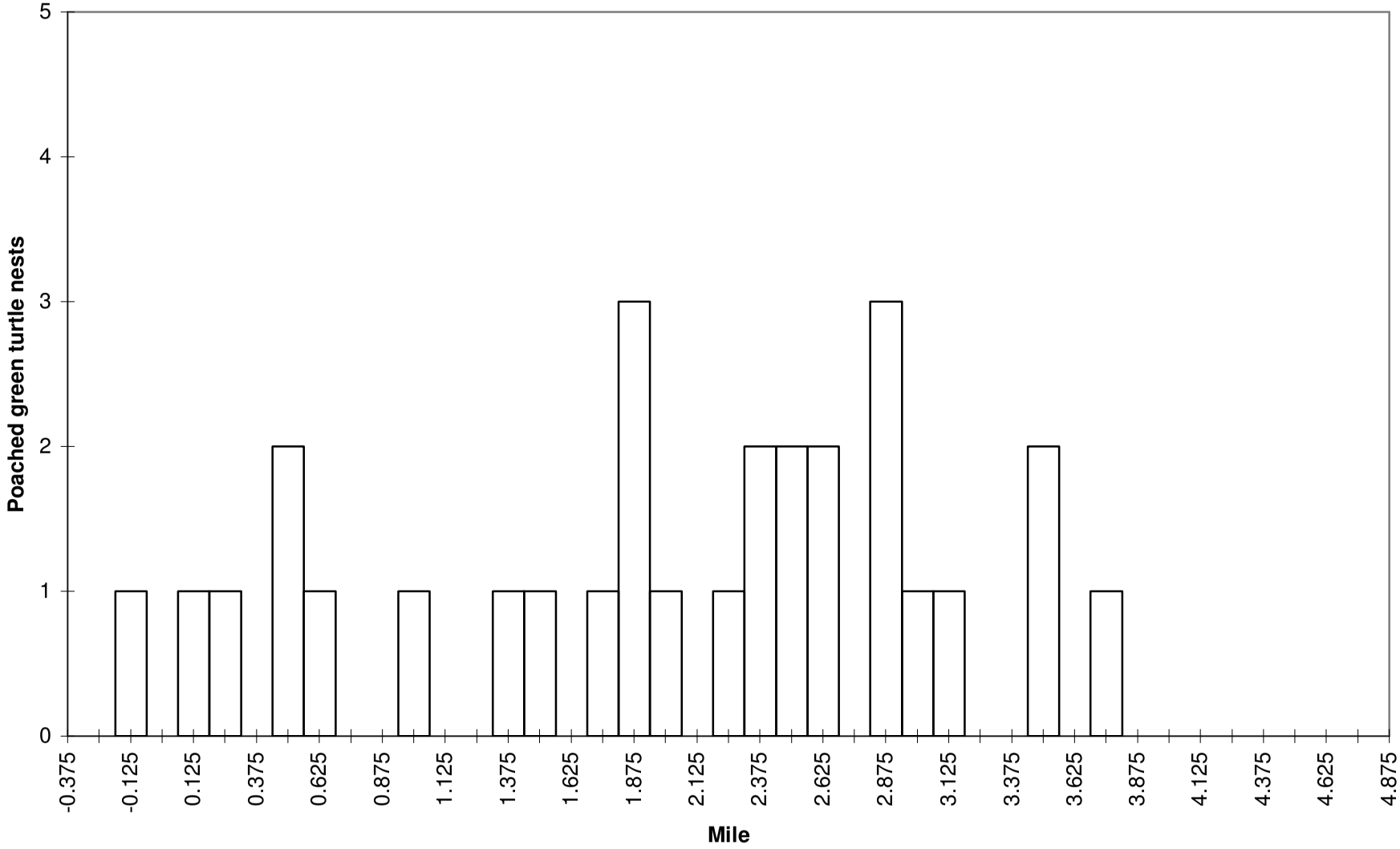


Figure 8. Rainfall.

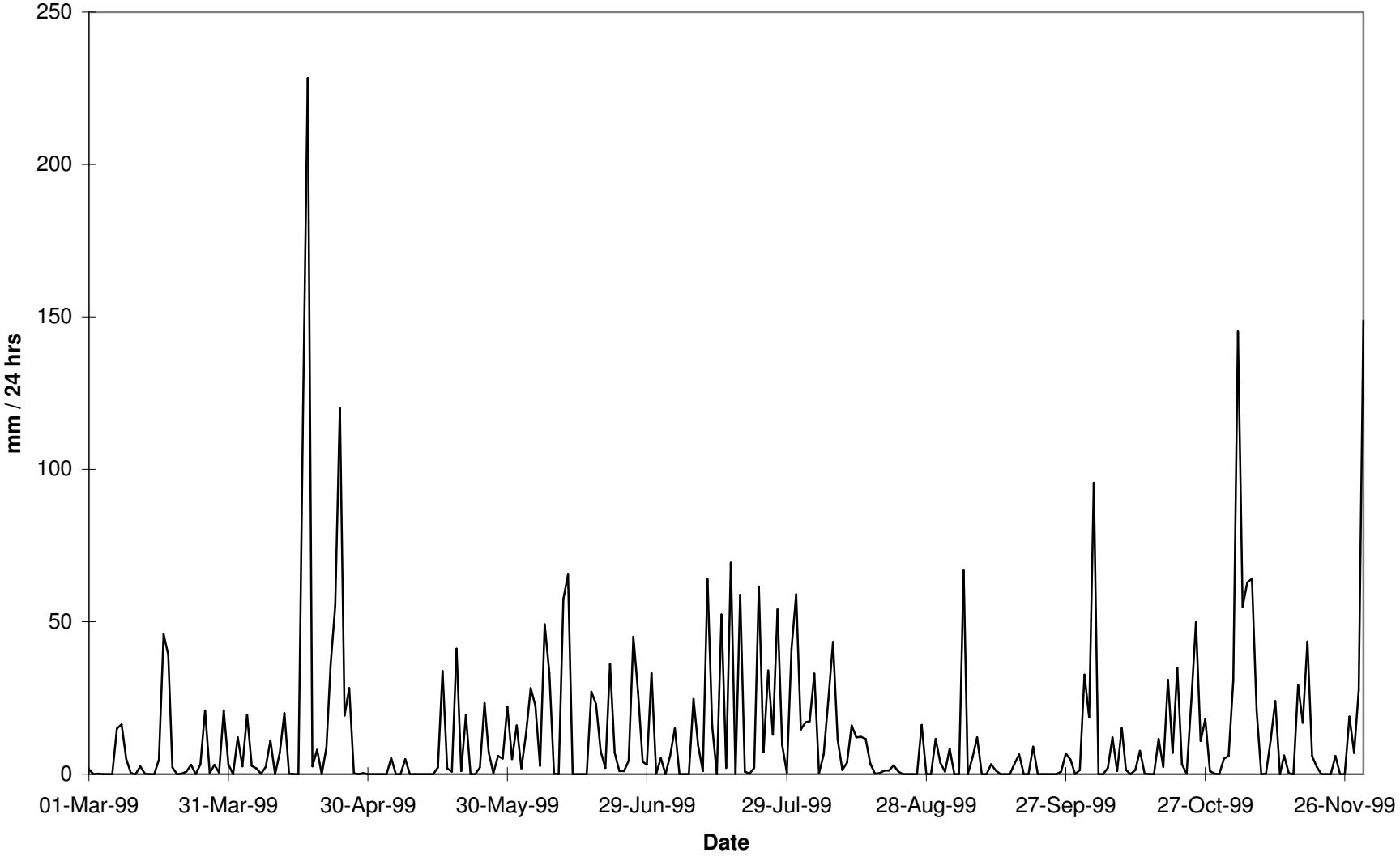


Figure 9. Temperature at 70 cm depth.

Figure 9a. Temperature at 70 cm depth, open zone.

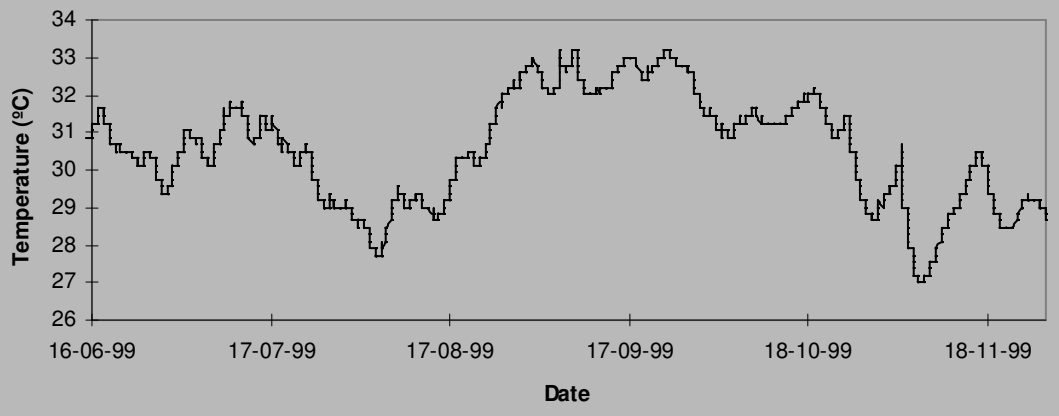


Figure 9b. Temperature at 70 cm depth, border zone.

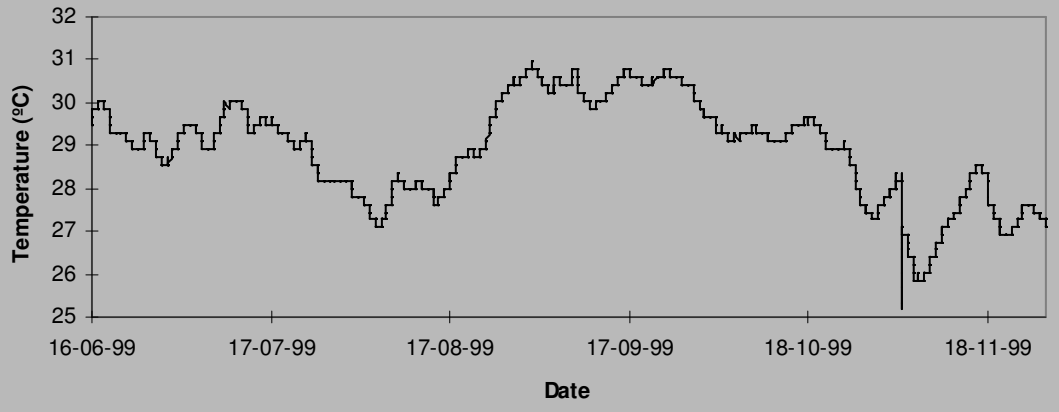


Figure 9c. Temperature at 70 cm depth, vegetation zone.

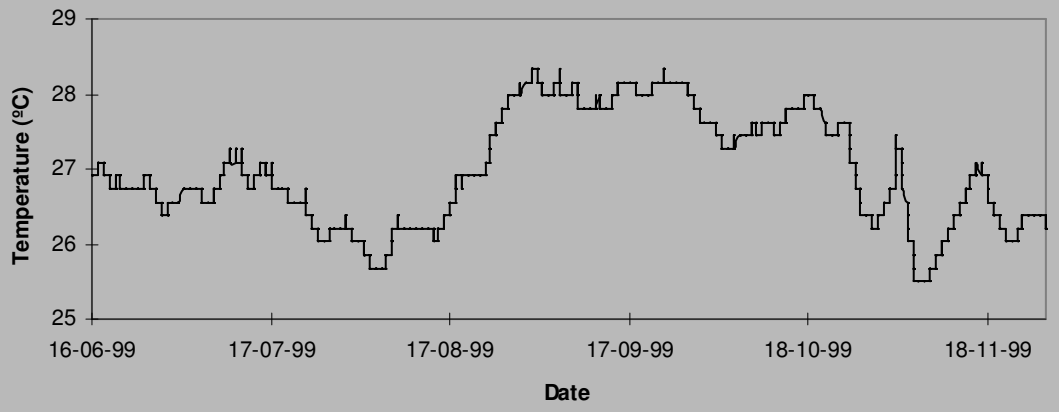
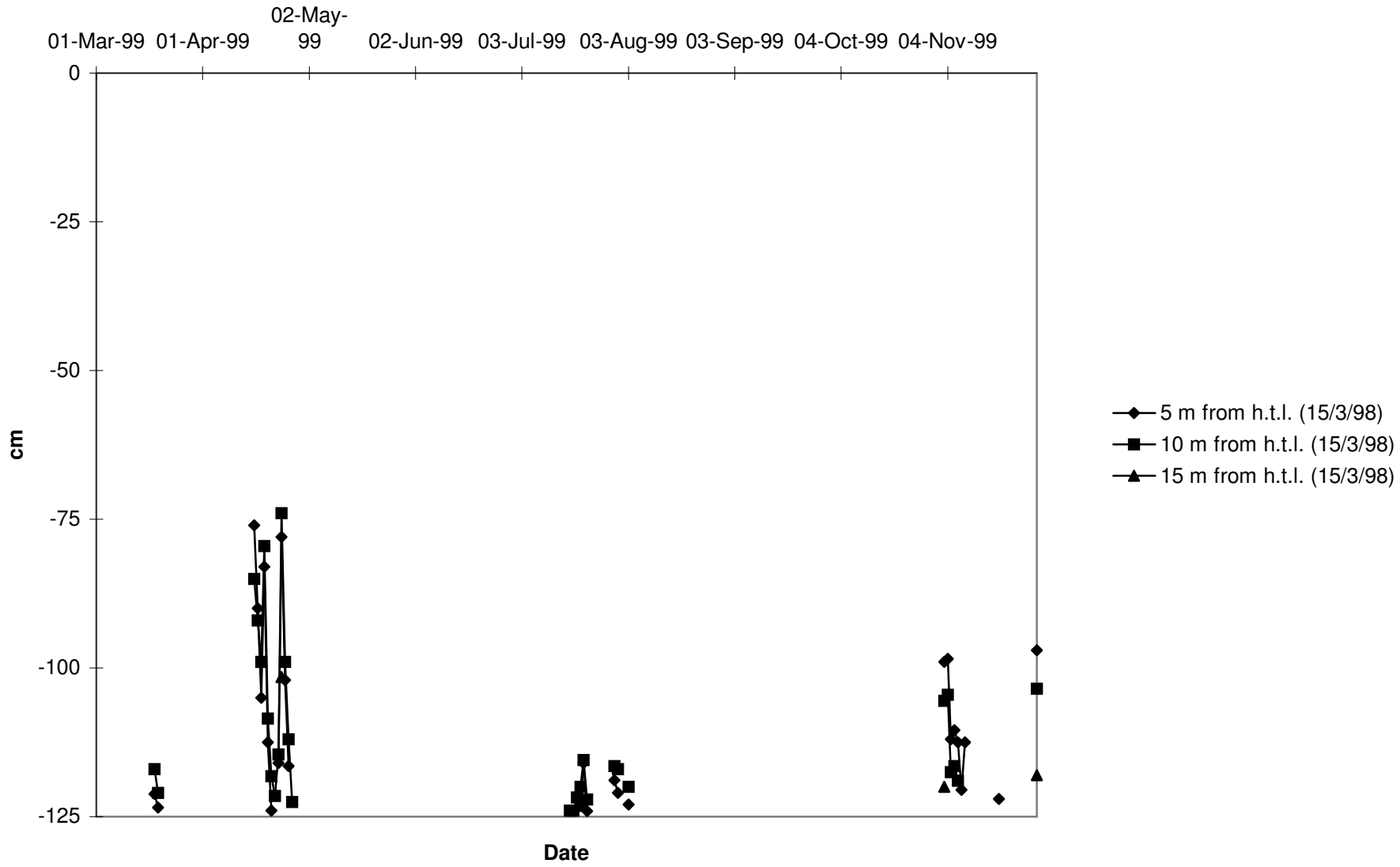


Figure 10. Ground water level.



APPENDIX 1. Sea Turtle Encounters During Regular Night Patrols

Date	Leatherbacks				Green turtles				Hawksbills			
	Newly tagged turtles	Previously tagged turtles	Renester	Total	Newly tagged turtles	Previously tagged turtles	Renesters	Total	Newly tagged turtles	Previously tagged turtles	Renesters	Total
11-jun-99				**0**				**0**				**0**
12-jun-99				**0**				**0**				**0**
13-jun-99				**0**				**0**				**0**
14-jun-99				**0**				**0**				**0**
15-jun-99				**0**				**0**				**0**
16-jun-99				**0**				**0**				**0**
17-jun-99				**0**				**0**				**0**
18-jun-99				**0**				**0**				**0**
19-jun-99				**0**		1		**1**				**0**
20-jun-99				**0**				**1**				**0**
21-jun-99			1	**1**	1			**2**				**0**
22-jun-99				**1**				**2**				**0**
23-jun-99				**1**	2			**4**				**0**
24-jun-99				**1**	1	1	1	**7**				**0**
25-jun-99		1		**2**			1	**8**				**0**
26-jun-99				**2**				**8**				**0**
27-jun-99				**2**	1			**9**				**0**
28-jun-99		1		**3**	1			**10**				**0**
29-jun-99				**3**	1			**11**				**0**
30-jun-99				**3**				**11**				**0**
1-jul-99				**3**	2	1		**14**	2			**2**
2-jul-99	1			**4**				**14**				**2**
3-jul-99				**4**	2		1	**17**	1			**3**
4-jul-99				**4**	5			**22**	1			**4**
5-jul-99		1		**5**	3	2		**27**				**4**
6-jul-99				**5**	6	1	1	**35**				**4**
7-jul-99				**5**	4	1		**40**				**4**
8-jul-99				**5**	2	2	1	**45**	1			**5**
9-jul-99				**5**		1		**46**				**5**
10-jul-99		1		**6**	4	1	2	**53**				**5**
11-jul-99				**6**	1	1		**55**		1		**6**
12-jul-99				**6**	3	2	1	**61**			1	**7**
13-jul-99				**6**	3	4		**68**				**7**
14-jul-99				**6**	1			**69**				**7**
15-jul-99				**6**	7	3	2	**81**				**7**
16-jul-99				**6**	7	2	1	**91**				**7**
17-jul-99				**6**	1	3	1	**96**				**7**
18-jul-99				**6**			1	**97**	1			**8**
19-jul-99				**6**	4	2	1	**104**				**8**
20-jul-99				**6**	1		1	**106**				**8**
21-jul-99				**6**	4	2	1	**113**				**8**
22-jul-99				**6**	1	3		**117**				**8**
23-jul-99				**6**	6	5	3	**131**				**8**
24-jul-99				**6**	4	5	3	**143**				**8**
25-jul-99				**6**	2	2		**147**				**8**
26-jul-99				**6**	5	7	4	**163**				**8**

27-jul-99	**6**	5	4	1	**173**		**8**
28-jul-99	**6**	6	3	6	**188**	1	**9**
29-jul-99	**6**	3	6	1	**198**		**9**
30-jul-99	**6**	5	6	4	**213**		**9**
31-jul-99	**6**	5	8	3	**229**		**9**
1-aug-99	**6**	13	3	2	**247**		**9**
2-aug-99	**6**	7	4	4	**262**		**9**
3-aug-99	**6**	4	1	2	**269**		**9**
4-aug-99	**6**	5	7	8	**289**		**9**
5-aug-99	**6**	3	2	8	**302**		**9**
6-aug-99	**6**	5	7	1	**315**		**9**
7-aug-99	**6**	3	1	8	**327**		**9**
8-aug-99	**6**	8	6	14	**355**		**9**
9-aug-99	**6**	6	2	3	**366**		**9**
10-aug-99	**6**	6	4	8	**384**		**9**
11-aug-99	**6**	8	3	7	**402**		**9**
12-aug-99	**6**	7	6	6	**421**		**9**
13-aug-99	**6**	8	2	9	**440**		**9**
14-aug-99	**6**	9	4	7	**460**		**9**
15-aug-99	**6**	2	1	4	**467**	1	**10**
16-aug-99	**6**	10	4	5	**486**		**10**
17-aug-99	**6**	5		6	**497**		**10**
18-aug-99	**6**	7	5	6	**515**		**10**
19-aug-99	**6**	1	1	8	**525**		**10**
20-aug-99	**6**	15	2	5	**547**		**10**
21-aug-99	**6**	5	5	4	**561**		**10**
22-aug-99	**6**	8	4	8	**581**		**10**
23-aug-99	**6**	8	4	12	**605**		**10**
24-aug-99	**6**	4	4	8	**621**		**10**
25-aug-99	**6**	5	2	6	**634**		**10**
26-aug-99	**6**	6	4	6	**650**		**10**
27-aug-99	**6**	9	5	4	**668**		**10**
28-aug-99	**6**	8	6	9	**691**		**10**
29-aug-99	**6**	7	5	8	**711**		**10**
30-aug-99	**6**	5	1	3	**720**	1	**11**
31-aug-99	**6**	8		8	**736**		**11**
1-sep-99	**6**	5	5	6	**752**		**11**
2-sep-99	**6**	2	1	5	**760**		**11**
3-sep-99	**6**	6	1	1	**768**		**11**
4-sep-99	**6**	7		4	**779**		**11**
5-sep-99	**6**	5	1	1	**786**		**11**
6-sep-99	**6**	3	3	6	**798**		**11**
7-sep-99	**6**	8	1	11	**818**		**11**
8-sep-99	**6**	2	2	3	**825**		**11**
9-sep-99	**6**	4		8	**837**		**11**
10-sep-99	**6**	3	2	8	**850**		**11**
11-sep-99	**6**	8	2	11	**871**		**11**
12-sep-99	**6**	6	1	9	**887**		**11**
13-sep-99	**6**	9		14	**910**		**11**
14-sep-99	**6**	7	1	1	**919**		**11**
15-sep-99	**6**	9	1	5	**934**		**11**
16-sep-99	**6**	2		8	**944**		**11**

17-sep-99				**6**	7	3	18	**972**				**11**
18-sep-99				**6**	6	2	10	**990**				**11**
19-sep-99				**6**	7	3	9	**1009**				**11**
20-sep-99				**6**	3	1	4	**1017**				**11**
21-sep-99				**6**	4		2	**1023**				**11**
22-sep-99				**6**	1	1	6	**1031**				**11**
23-sep-99				**6**	5	2	7	**1045**				**11**
24-sep-99				**6**	4	1	4	**1054**				**11**
25-sep-99				**6**	11	1	4	**1070**				**11**
26-sep-99				**6**	10	2	15	**1097**				**11**
27-sep-99				**6**	7	1	17	**1122**				**11**
28-sep-99				**6**	6	2	14	**1144**				**11**
29-sep-99				**6**	4		4	**1152**				**11**
30-sep-99				**6**	11	1	9	**1173**				**11**
1-oct-99				**6**	10	5	10	**1198**				**11**
2-oct-99				**6**	5		5	**1208**				**11**
3-oct-99				**6**	8	1	9	**1226**	1			**12**
4-oct-99				**6**	5	2	9	**1242**				**12**
5-oct-99				**6**	6		4	**1252**				**12**
6-oct-99				**6**	2		11	**1265**				**12**
7-oct-99				**6**	4		9	**1278**				**12**
8-oct-99				**6**		1	8	**1287**				**12**
9-oct-99				**6**	1		8	**1296**				**12**
10-oct-99				**6**	3		8	**1307**				**12**
11-oct-99				**6**	3	1	5	**1316**				**12**
12-oct-99				**6**			4	**1320**				**12**
13-oct-99				**6**	1		5	**1326**				**12**
14-oct-99				**6**	1		4	**1331**				**12**
15-oct-99				**6**	2	1	10	**1344**				**12**
16-oct-99				**6**	6		6	**1356**				**12**
17-oct-99				**6**	1		8	**1365**				**12**
18-oct-99				**6**	2	1	6	**1374**				**12**
19-oct-99				**6**	1	1	2	**1378**				**12**
20-oct-99				**6**	1		3	**1382**				**12**
21-oct-99				**6**	1		2	**1385**				**12**
22-oct-99				**6**		1	3	**1389**				**12**
23-oct-99				**6**			2	**1391**	1			**13**
24-oct-99				**6**				**1391**				**13**
25-oct-99				**6**	1		3	**1395**				**13**
26-oct-99				**6**			1	**1396**				**13**
27-oct-99				**6**	1		1	**1398**				**13**
28-oct-99				**6**			1	**1399**				**13**
29-oct-99				**6**				**1399**				**13**
30-oct-99				**6**				**1399**				**13**
31-oct-99				**6**				**1399**				**13**
Total	**1**	**4**	**1**	**6**	**551**	**239**	**609**	**1399**	**11**	**1**	**1**	**13**

APPENDIX 2. Sea Turtle Encounters During Additional Night Patrols

Date	Section	Green Turtles				Hawksbill	
		Newly tagged turtles	Previously tagged turtles	Renesters	Total	Newly tagged turtles	Total
15-jun-99	Mile 12-15	3	0	0	**3**		
01-sep-99	Mile 6-10	4	3	4	**50**		**0**
02-sep-99	Mile 6-10	36	3	2	**91**		**0**
06-sep-99	Mile 6-10	19			**110**		**0**
07-sep-99	Mile 6-10	30	2	3	**145**		**0**
08-sep-99	Mile 6-10	17			**162**		**0**
09-sep-99	Mile 6-10	19		5	**186**		**0**
10-sep-99	Mile 6-10	6		2	**194**		**0**
11-sep-99	Mile 6-10	18	2	4	**218**		**0**
13-sep-99	Mile 5-8	11	3	4	**236**		**0**
13-sep-99	Mile 8-10	14		2	**252**		**0**
14-sep-99	Mile 5-8	20	1	4	**277**		**0**
14-sep-99	Mile 8-10	25			**302**		**0**
15-sep-99	Mile 5-8	24	1	3	**330**		**0**
15-sep-99	Mile 8-10	17	2		**349**		**0**
15-sep-99	Mile 10-12	12	1	3	**365**		**0**
16-sep-99	Mile 6-10	9		1	**375**		**0**
17-sep-99	Mile 6-10	16	3	3	**397**		**0**
18-sep-99	Mile 6-10	14	3	1	**415**		**0**
19-sep-99	Mile 6-10	10	1	3	**429**		**0**
20-sep-99	Mile 5-8	17	1	3	**450**		**0**
20-sep-99	Mile 8-10	13		1	**464**		**0**
20-sep-99	Mile 10-12	20		3	**487**		**0**
23-sep-99	Mile 5-8	13	3	11	**514**		**0**
23-sep-99	Mile 8-10	13	1	8	**536**		**0**
23-sep-99	Mile 10-12	6	1		**543**		**0**
28-sep-99	Mile 5-8	23	1	6	**573**		**0**
28-sep-99	Mile 8-10	22	1	1	**597**	1	**1**
30-oct-99	Mile 15-2 5/8	3	1	2	**603**		**1**
Total		**490**	**34**	**79**	**603**	**1**	**1**

APPENDIX 3. Notes and Anecdotal Information on Illegal Harvest

The main market for green turtle products is Limón but trade occurs all along the Caribbean coast of Costa Rica. In 1999, the enforcement of legislation protecting green turtle in Costa Rica was stricter than previously. Although meat and eggs were sold in Limón and Tortuguero, sale was rarely in the open. The increased restriction on sale of turtle products and increased protection in Tortuguero National Park limited illegal harvest of green turtles in 1999. One result was an increase in the price of turtle meat to ¢1000 (approx. US$3.4) per kilo, in Limón. Green turtle eggs were sold for ¢100-¢150 per egg, mainly by persons walking around the market and the bars in Limón (and in Tortuguero).

In Tortuguero, the majority of poached green turtle nests are taken by persons which sell the eggs in order to buy illegal drugs and alcohol.