Sea Turtle Monitoring and Research Report

Pacuare Nature Reserve

2016

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Endangered Wildlife Trust

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1. Introduction

1.1. Pacuare Nature Reserve

The Endangered Wildlife Trust (EWT) is an English NGO that has been committed to sea turtle and wildlife conservation in Costa Rica since 1989. The Trust was founded by John Denham, who visited the Caribbean coast of Costa Rica in the late 1980s seeking a piece of property on which to build a holiday home. Noticing the alarmingly high level of sea turtle egg harvest, he instead created EWT to raise funds and purchased 800 hectares of land fronting 5.7 kilometers of sea turtle nesting beach. The property was a mix of deforested farmland and small pockets of rainforest, which naturally reforested the cleared areas once the land was protected. In addition to providing habitat for the diverse flora and fauna that had been threatened by habitat degradation, reforestation of land adjacent to the beach made beach access more difficult for poachers and served as a natural deterrent to sea turtle egg poaching.

Initially, nest poaching at PNR was estimated to be as high as 95%, which was then a common problem throughout Central America. The Endangered Wildlife Trust made various cooperative efforts with the Costa Rican Ministry of Environment (MINAE) to protect sea turtles during the annual nesting season. By 1991, the property was officially protected as Pacuare Nature Reserve (PNR). By the start of the 1994 nesting season, a comprehensive sea turtle monitoring and conservation program was underway, started by John's daughter Alexandra and conducted with the help of a small team of volunteers.

The project has grown enormously in the decades since, and EWT now operates research stations at the northern and southern limits of the Reserve. Nest poaching on the 5.7-kilometer beach has been reduced to under 5%, and the Reserve hosts some 211 species of bird, 24 species of mammal, 44 species of reptile, and 21 species of amphibian on the now 1050 hectares of protected rainforest. The Reserve is also home to a diverse array of invertebrates, trees and plant life, and aquatic species inhabiting the surrounding canal and shoreline. The Reserve attracts biologists, conservationists, and researchers from around the world as well as students and independent volunteers who visit to learn about nesting sea turtles and experience the amazing biodiversity flourishing at the Reserve.

1.2. Location of Pacuare Nature Reserve

Pacuare Nature Reserve is located along the Caribbean coast of Costa Rica. The Reserve is 30 kilometers northwest of the port of Limón and 45 kilometers southeast of Tortuguero. Tortuguero Canal separates PNR from the mainland to the west. The Reserve's northern border is one kilometer south of the Pacuare River mouth and the southern border is at Mondonguillo Lagoon. The Reserve's sea turtle monitoring project operates on the 5.7 kilometers of beach protected by PNR (*Figure 1*). Two research stations, one at the northern limit and one at the southern limit, are operational throughout the sea turtle nesting season.

1.3. Sea Turtle Species

Three of the world's seven species of sea turtle nest in Pacuare. The high-energy and erosion-prone beaches of the Caribbean coast of Central America, more specifically of Costa Rica and northern Panama, hold the third most important nesting ground for the Northwest Atlantic Ocean subpopulation of the leatherback turtle (*Dermochelys coriacea*). The leatherback nesting season occurs between February and August, and Pacuare Nature Reserve receives an average of 770 leatherback nests every year.

Two species of hard-shelled sea turtle also nest in Pacuare: the green turtle (*Chelonia mydas*) and the hawksbill turtle (*Eretmochelys imbricata*). The green turtle nesting season is between June and November, and the world's largest nesting colony of green turtles is located only 45 kilometers northwest of Pacuare at Tortuguero National Park. Critically endangered hawksbill turtles nest throughout the season, though in much smaller numbers. Other monitoring programs have also reported loggerhead turtle (*Caretta caretta*) nesting in the area, but encounters are rare.

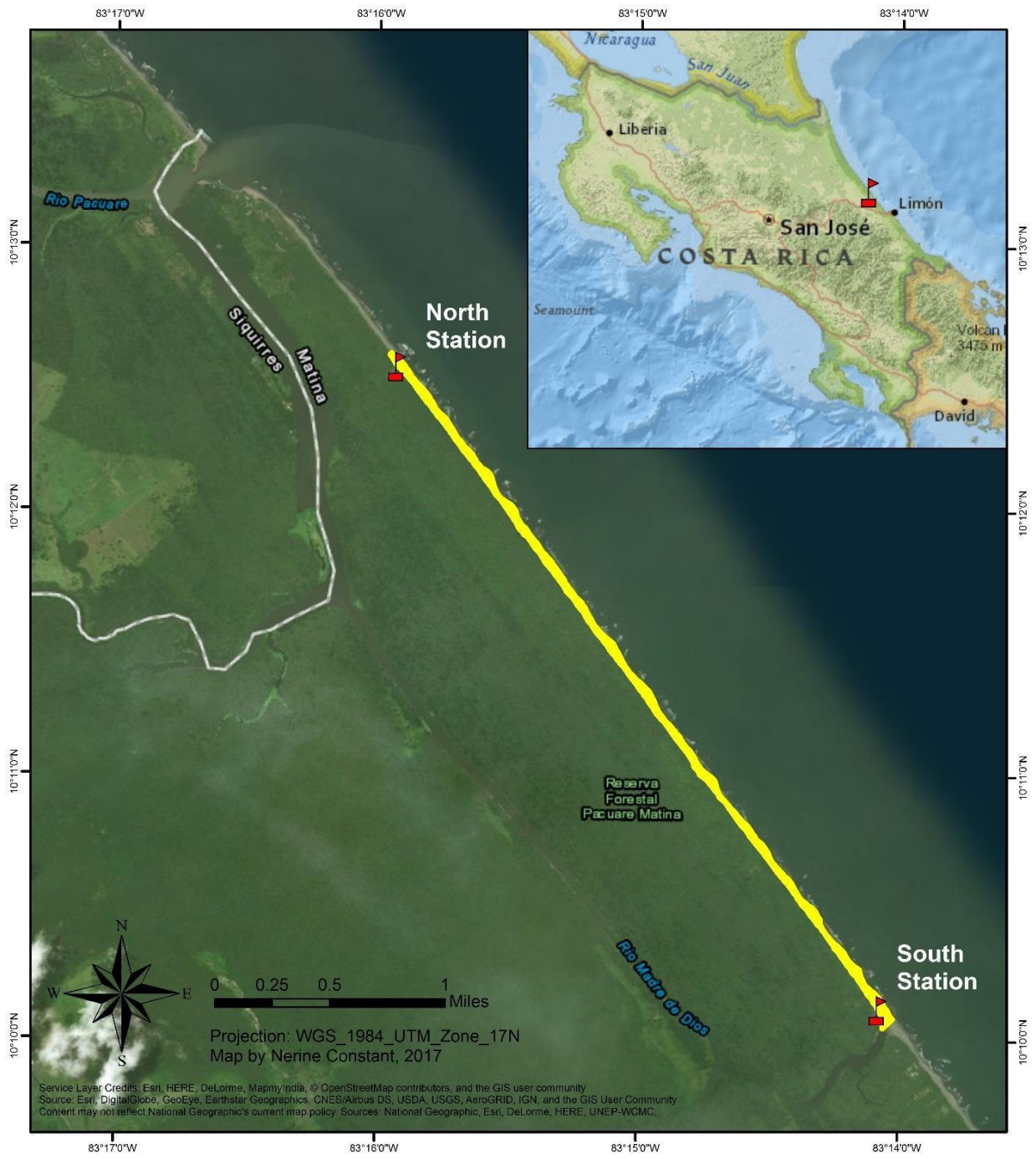

Figure 1. Map of Pacuare Nature Reserve showing its location within Costa Rica (inset map) and the extent of beach monitoring (in yellow). Map credit: Nerine Constant

2. Methodology

2.1. Preparation

To start the season fully equipped, PNR staff cleaned equipment, prepared offices, and purchased missing equipment. Field Coordinators trained Field Assistants with an intensive field techniques course to ensure they were suitably prepared for the onset of the nesting season. The course included lessons on sea turtle ecology and biology, species identification, safe working practices, use of equipment, data collection protocol, tagging methodology, nest relocation and triangulation procedures, beach patrol ethics and leadership, and health and safety practices.

We divided the beach into monitoring sectors by placing numbered wooden markers at 25-meter intervals along the entire 5.7-kilometer beach. Markers at 100-meter intervals were numbered with whole numbers from 0 in the south to 57 in the north, and markers in between were numbered in increments of 0.1 from the previous 100-meter marker (e.g. the southernmost 100 meters of the study area were marked 0, 0.1, 0.2, 0.3, and 1).

2.2. Beach Patrols and Nesting Surveys

We conducted nightly beach patrols from February 18th to September 30th to monitor all sea turtle activities on the beach and to keep the poaching rate to an absolute minimum. Either a Field Coordinator or Field Assistant led each patrol, accompanied by small groups of volunteers. Each group patrolled for a minimum of four hours, with patrols starting from both stations at 20:00, 22:00 and 00:00. This schedule allowed us to maximize turtle encounters by having multiple patrols on the beach simultaneously and covering the beach until almost sunrise. During night patrols, we encountered tracks and turtles and performed tagging, measuring, and nest relocation protocols.

For each activity, we recorded the following data in a waterproof notebook.

- **Patrol leader's name**

- **Date:** The patrol date (does not change after midnight, so all patrols in one night have the same date recorded)
- **Time:** Recorded in 24-hour time the minute the patrol encountered the turtle
- **Sea turtle species:**
    - **DC:** *Dermochelys coriacea* (Leatherback, Baula)
    - **CM:** *Chelonia mydas* (Green, Verde)
    - **EI:** *Eretmochelys imbricata* (Hawksbill, Carey)
- **Activity type:**
    - **S**alida **F**alsa (False Crawl): An activity that did not result in a nesting attempt
    - **N**o **P**uso (Did Not Lay): The turtle dug a body pit, but did not oviposit
    - **N**o **S**é (Not Confirmed): An activity with all the characteristics of a nest, but the patrol did not witness oviposition
    - **I**n **S**itu: A confirmed nest that the patrol left in the turtle's original nesting site
    - **R**eubicado (Relocated): A confirmed nest that the patrol relocated to a safer site
- **Zone:** Vertical area of the beach where the activity occurred
    - **V**egetación: In the vegetation
    - **A**lta: Upper part of the beach
    - **B**aja: Lower part of the beach
    - **M**area: Below the high tide line

When the turtle was encountered in addition to the track, we also recorded the following information.

- **Stage of nesting process:** The turtle's behavior when encountered by the patrol
    - **S**aliendo (Emerging): Emerging from the water or searching for a suitable nest site
    - **B**añando (Bodypitting): Making a body pit with her front flippers
    - **E**xcavando (Digging): Digging the egg chamber
    - **P**oniendo (Laying): Oviposition, or laying eggs
    - **T**apando (Covering): Covering the egg chamber with her rear flippers
    - **C**amuflando (Camouflaging): Camouflaging her nest

    - **R**egresando (Returning): Returning to the sea
- **Tagging data** (see *2.4. Individual Sea Turtle Identification*): Left and right flipper tag number, PIT tag number, whether tags were old or newly applied, and evidence of lost tags (old tag holes and notches)
- **Size measurements** (see *2.5. Biometric Data*): Carapace measurements in centimeters
- **Body condition:** Any notable observations on turtle body condition, including injuries, deformities, and parasites

For in situ and relocated nests, we also recorded the following information.

- **Nest depth:** Measured in centimeters from surface to bottom of egg chamber
- **Egg count:** The number of fertile and infertile (yolkless) eggs laid in the nest
- **Nest location measurements** (see *2.7. Nest Triangulation*)

2.3. Morning Census

We conducted the morning census at dawn to monitor the status of in situ and relocated nests; record evidence of poaching, erosion, or hatching activity; and conduct nest excavations (see *2.8. Nest Excavation*). We also marked unconfirmed nests with flagging tape if we observed evidence of hatching that confirmed oviposition. Morning census also functioned as the final patrol, allowing us to record any turtle activities that occurred after the last night patrol.

2.4. Individual Sea Turtle Identification

2.4.1. Flipper Tagging

Once turtles finished laying, we marked untagged turtles with metal flipper tags using tagging pliers. Each tag has a unique series of letters and numbers that allows for individual identification. Leatherbacks were marked with Monel tags placed in their left and right rear flippers and hard-shelled species were tagged with Inconel tags in the second scale of their left and right front flippers (*Figure 2*).

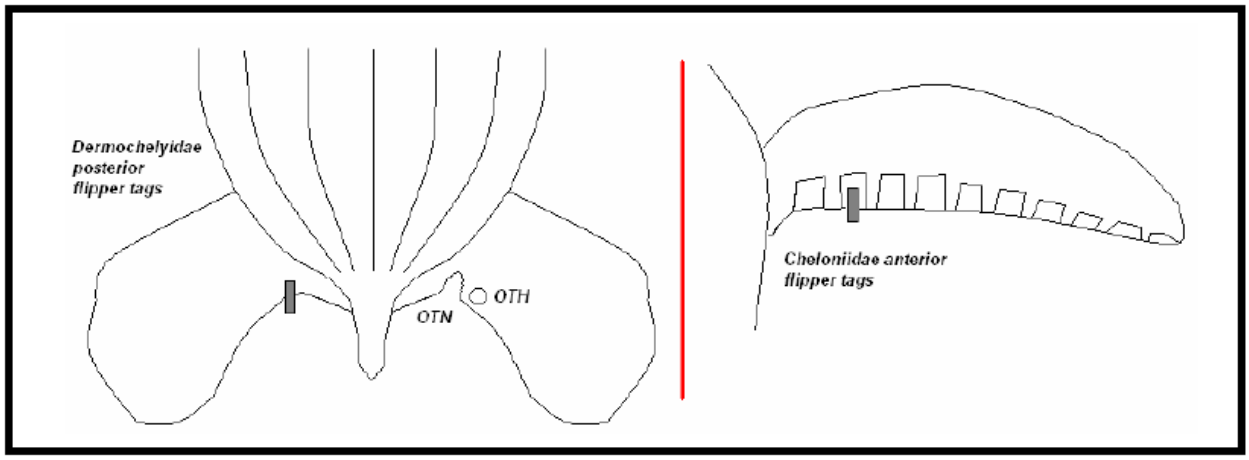

Figure 2. Flipper tagging locations for leatherbacks (left) and hard-shelled species (right). Evidence of lost tags noted as old tag notch (OTN) and old tag hole (OTH). Image credit: 2009 Sea Turtle Monitoring Program Report, Pacuare Reserve.

2.4.2. Passive Integrated Transponder (PIT) Tagging

As a secondary individual identification method, we also marked turtles with Passive Integrated Transponder (PIT) tags after scanning for existing tags. These tags use a transponder the size of a grain of rice that provides a unique series of letters and numbers when read with a scanner. We injected PIT tags into the front muscle of the right shoulder.

2.5. Biometric Data

We counted eggs during oviposition (for nests left in situ) and during nest relocations. Leatherbacks also lay smaller yolkless eggs after the fertilized eggs, which we counted separately. When handling eggs, we always wore medical gloves to protect humans, turtles, and eggs. For leatherbacks, we measured curved carapace length (CCL) along the right side of the central ridge from the nuchal notch following the curving shape of the carapace to the tip of the caudal peduncle (*Figure 3 A.I, B.I*). We also noted if the caudal peduncle was complete or incomplete. We measured the curved carapace width (CCW) across the widest part of the carapace from the outer carapace ridges (*Figure 3 A.II, B.I*). For green turtles and hawksbills, we

measured CCL and CCW in a similar manner, down the center of the carapace and at the widest point respectively (*Figure 3 B.II*).

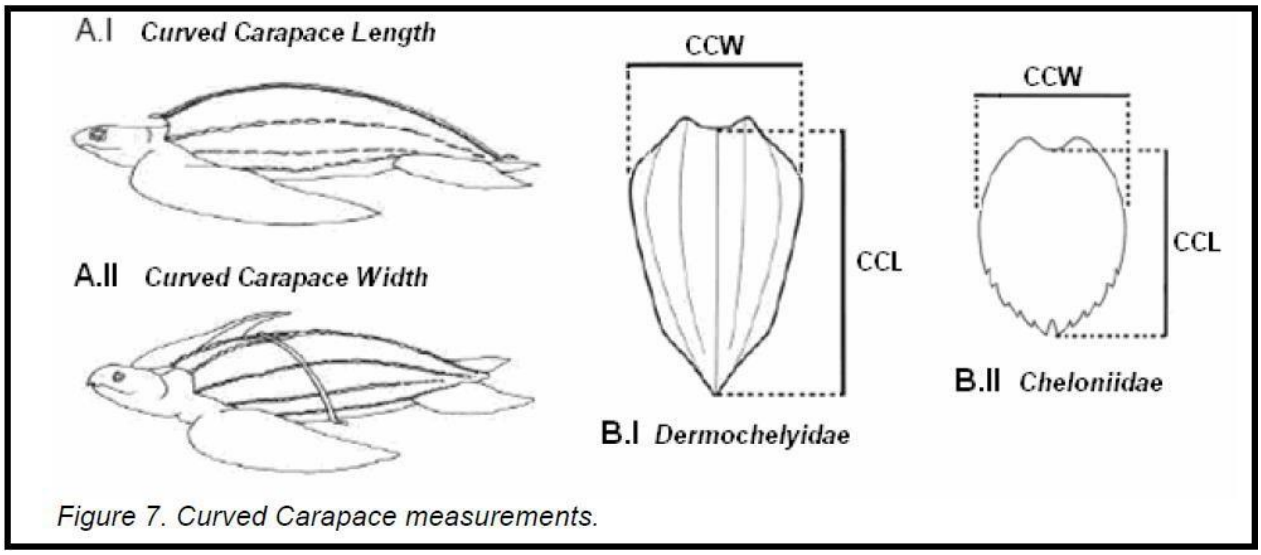

Figure 3. Measurement protocols for leatherbacks (A, B.I) and hard-shelled species (B.II). Image credit: 2009 Sea Turtle Monitoring Program Report, Pacuare Reserve.

2.6. Nest Relocation

We relocated nests that were laid in areas prone to nest failure due to erosion or elevated microbial content. If we encountered the turtle before oviposition and determined it was necessary to relocate the nest, we waited until the turtle had finished digging the egg chamber before placing a sterile plastic bag inside the nest to collect the eggs as they were laid. If the turtle had already finished laying and we determined the nest was at risk, we used a metal probe to find the egg chamber. We carefully transferred the eggs to an appropriate relocation site as near to the original nesting location as possible. Relocation sites were selected to minimize risk of erosion and elevated microbial content. To rebury the eggs, we dug a chamber matching the depth (70 centimeters for leatherbacks) and shape of original nest and placed the eggs in the same order as they were laid. We mimicked the turtle covering and camouflaging process, and we also cleared our footprints to prevent detection by potential poachers.

2.7. Nest Triangulation

We triangulated all in situ and relocated nests, which allowed us to return after the incubation period and find the exact location of the egg chamber when conducting nest excavations (see 2.8. *Nest Excavation*). We measured from the center of the chamber to the three closest sector marker posts using a 30-meter tape measure, and we recorded these distances to the nearest centimeter (*Figure 4*).

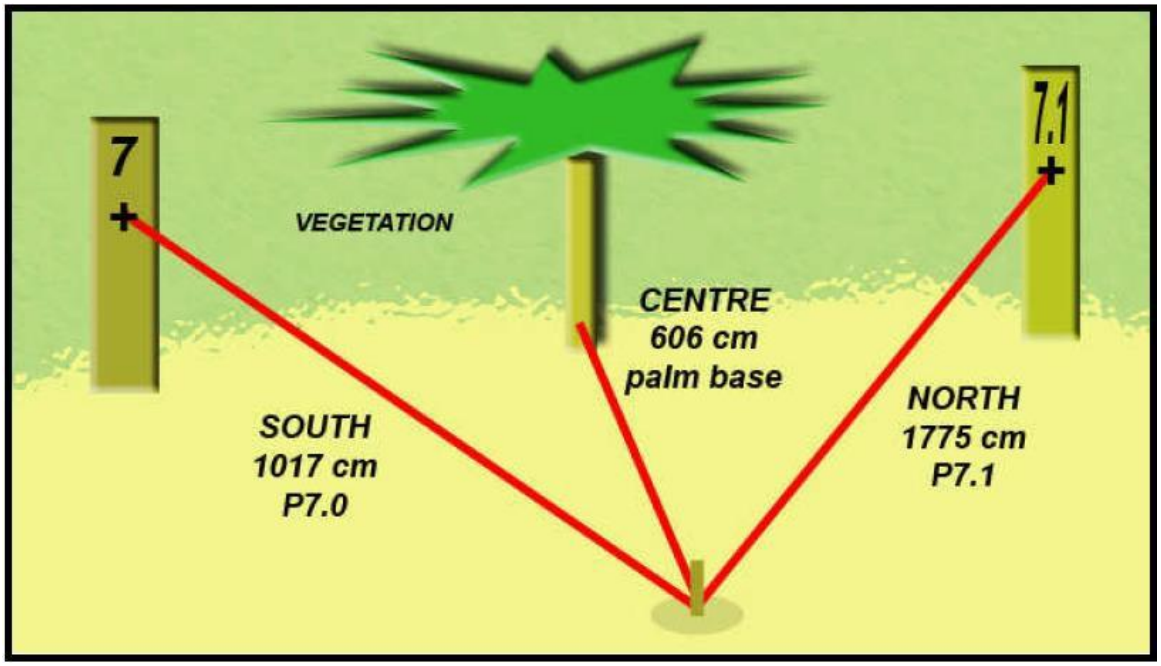

Figure 4. Example nest triangulation protocol. Image credit: Image credit: 2009 Sea Turtle Monitoring Program Report, Pacuare Reserve.

2.8. Nest Excavation

To calculate hatching and emerging success and evaluate beach productivity in terms of hatchling production, we conducted nest excavations for all in situ and relocated nests. We also excavated nests located using hatching evidence during morning census. Within five days of hatching activity or by the full 70-day incubation period for nests with no hatching activity reported, we exhumed the contents of nests. We wore medical gloves to protect any trapped hatchlings and avoid contact with decomposing nest contents. We recorded depth to the first and last egg and width of the egg chamber to the nearest millimeter.

We separated nest contents into the following categories.

- Hatched eggs: empty shells
- Unhatched eggs: whole eggs
- Yolkless eggs: small, misshapen eggs
- Pipped alive or dead hatchlings: hatchling pierced the shell with egg tooth but did not completely emerge from the egg
- Alive or dead hatchlings: hatchling completely left its shell

We counted and recorded all nest contents and opened any unhatched eggs to determine if the egg was undeveloped or if the embryo had died during development. Undeveloped eggs were recorded when only the yolk and albumen were visible. If blood vessels or an embryo were visible, we recorded phase of embryonic development, determined by percentage of egg volume occupied by the embryo (*Figure 5*).

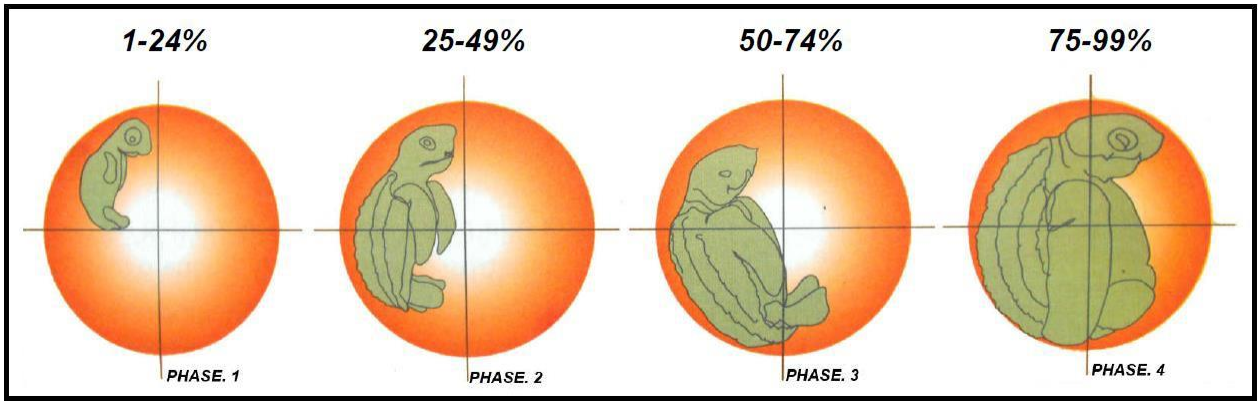

Figure 5. Protocol for categorizing embryos in unhatched eggs. Early Phase 1 embryos may be so small that only tiny black eyes are present, and late Phase 4 embryos appear fully developed with only a small yolk sack remaining. Image credit: 2009 Sea Turtle Monitoring Program Report, Pacuare Reserve.

We also recorded evidence of predation by crabs and fly larvae, the presence of mites (ácaros) and fungus, and whether eggs had been damaged by roots or appeared to have been exposed to high incubation temperatures ("cooked").

3. Results

3.1. Leatherback Turtles

3.1.1. Temporal Distribution

There were 744 leatherback turtle nesting activities in PNR from February 29th to July 30th, 2016. Of these, 58.3% (n=434) were nests and 41.7% (n=310) were false crawls. The season reached its peak by the end of April and start of May 2016 (*Figure 6*). This corroborates historical data. Activities between the 29th of March and the 12th of May account for 24.2% (n=180) of the total number of activities recorded during the nesting season (*Figure 6*). More than 41% (n=306) of all leatherback activities and nearly 39% (n=168) of all nests recorded occurred between weeks 8 and 11 of the 2016 nesting season, from April 18th to May 15th (*Figure 6, Figure 7*). The nights with the three highest recorded nesting activities were:

- May 1st with 25 activities (14 nests and 11 false crawls),
- May 3rd with 19 activities (11 nests and 8 false crawls),
- And May 11th with 25 activities (17 nests and 8 false crawls).

Comparing the 2016 nesting season data with historical data reveals that 2016 was an exceptionally low nesting season (*Figure 8*). The 2016 nesting season was the lowest recorded in 23 years of monitoring conducted by PNR. The next lowest season was 2013, which exceeded 2016 by 18 nests (*Figure 8*). The total number of nests laid in 2016 (n=434), was lower than the total for the single month of April in 2009 (n=466).

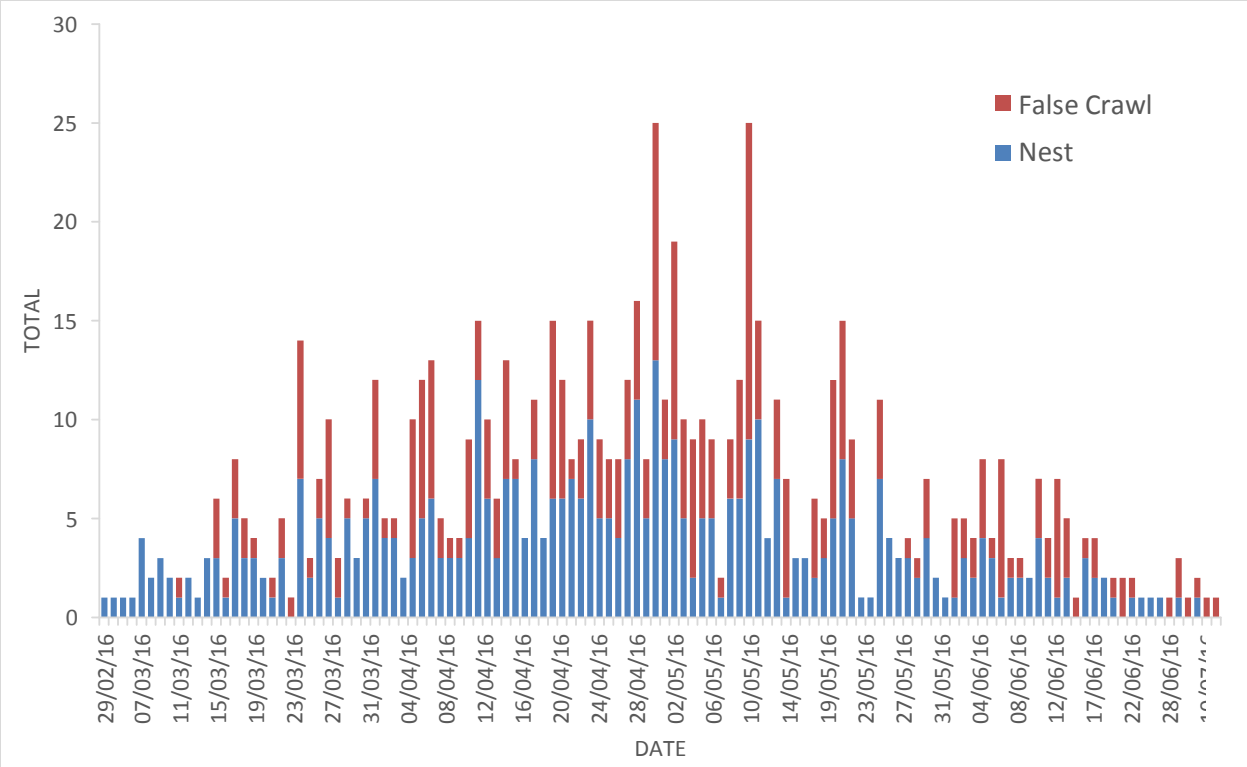

Figure 6. Temporal distribution of leatherback nesting activities in 2016.

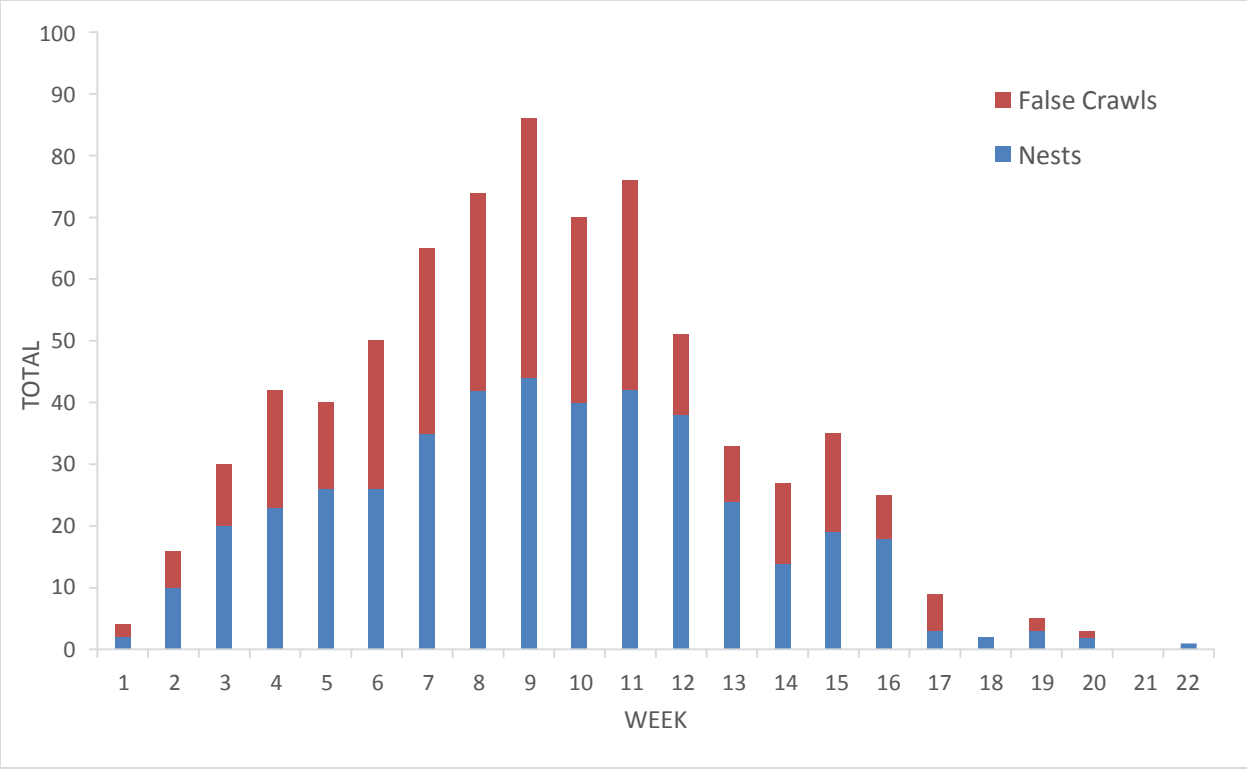

Figure 7. Number of leatherback nesting activities per week in 2016.

Figure 8. Number of leatherback nests per year in PNR since 1994. No data reported for 1998.

3.1.2. Spatial Distribution

Activities were distributed evenly over the 5.7-kilometer monitoring area (*Figure 9, Figure 10*). South sectors (0-30) received 52.8% (n=229) of the recorded nests and North sectors (30.1-56.3) received the remaining 47.2% (n=205) (*Table 1*).

The average nesting density for Pacuare Nature Reserve was 86.8 nests per kilometer. The portion of the beach with the highest density of nesting activity was near the south station, between sectors 0 and 1 (*Figure 9*). We recorded 26 nests and 6 false crawls in the southernmost 100 meters alone, which corresponds to 6.2% of the total number of nests and 4.4% of all recorded activities.

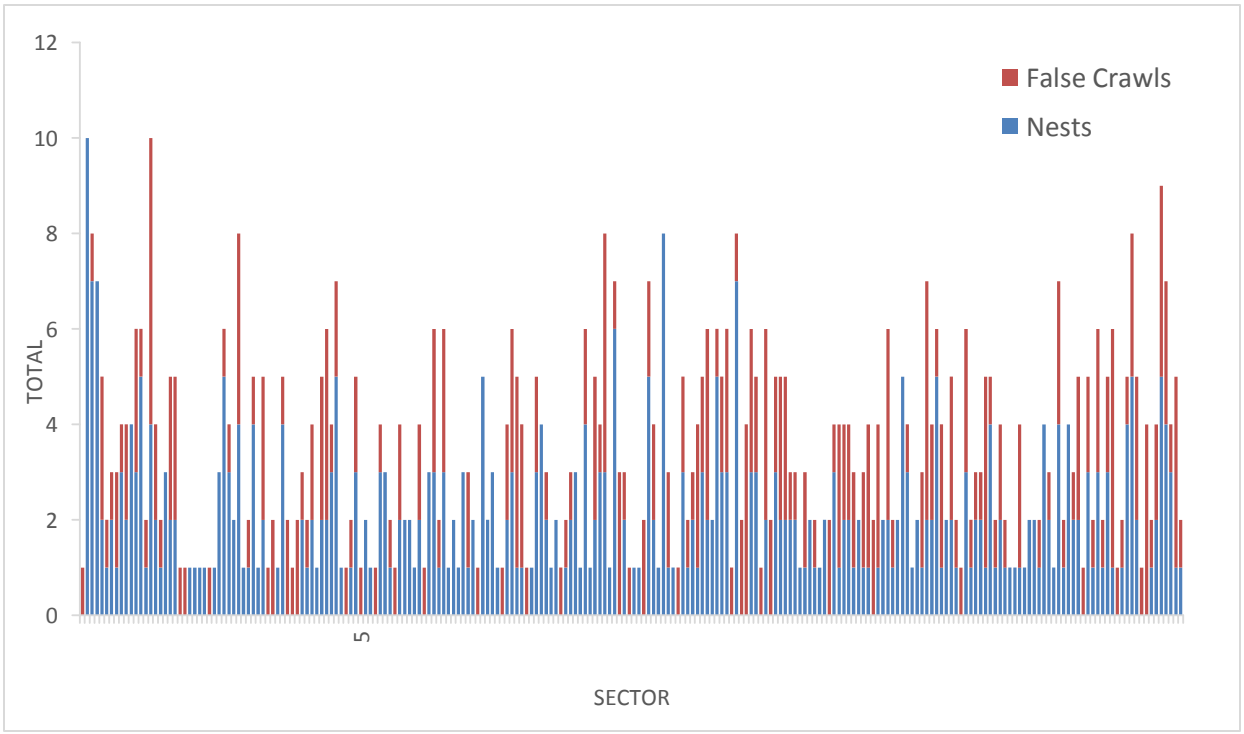

Figure 9. Number of leatherback activities per 25-meter sector in 2016.

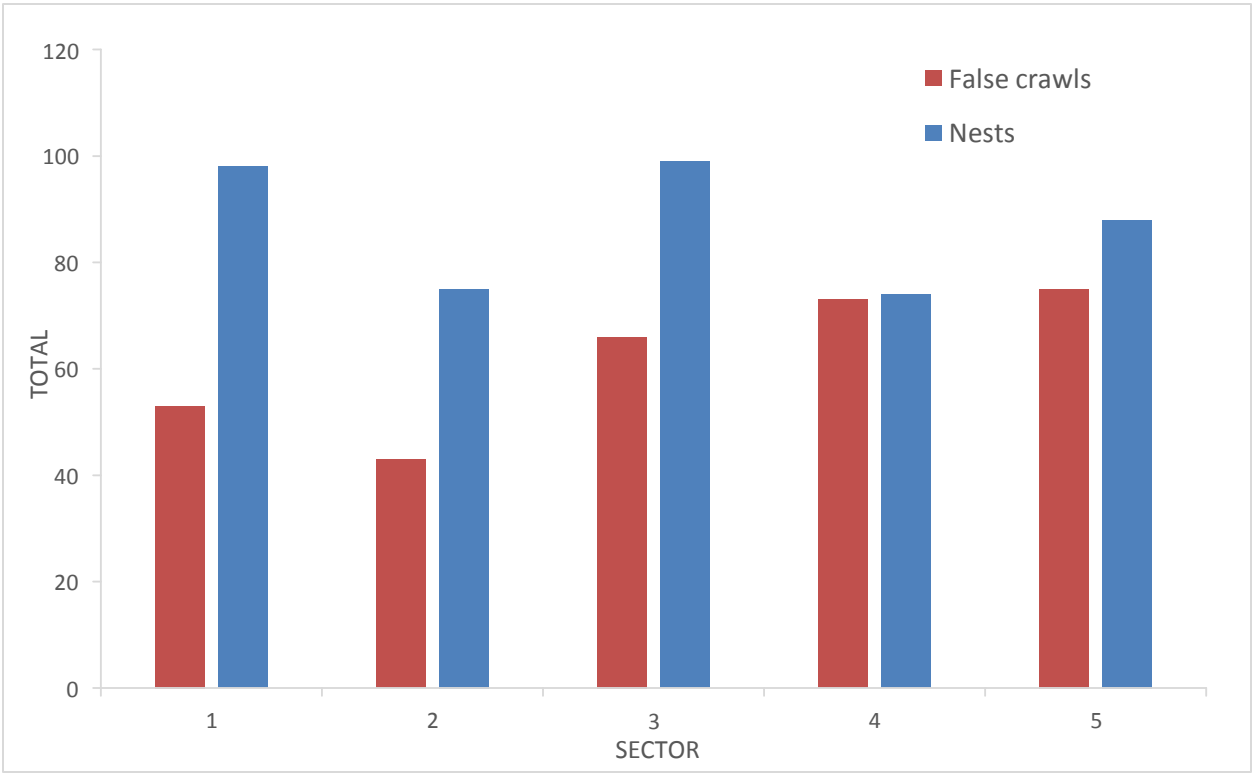

Figure 10. Number of leatherback activities per 1.14-kilometer sector in 2016.

Table 1. Number and percent of leatherback activities per 1.14-kilometer sector in 2016.

Sector	Nests	%	False Crawls	%	Total	%
1	98	22.6	53	17.1	151	20.3
2	75	17.3	43	13.9	118	15.9
3	99	22.8	66	21.3	165	22.2
4	74	17.1	73	23.5	147	19.8
5	88	20.3	75	24.2	163	21.9

3.1.3. Timing of Activity

During the 2016 season, all encounters with leatherbacks occurred between 18:00 and 6:00 (*Figure 11*). Of all activities, 70.6% (n=525) were recorded between 22:00 and 2:00 (*Figure 11*). The peak interval for leatherback activity was between 00:00 and 1:00, with 21.0% (n=156) of activities recorded during this time (*Figure 11*).

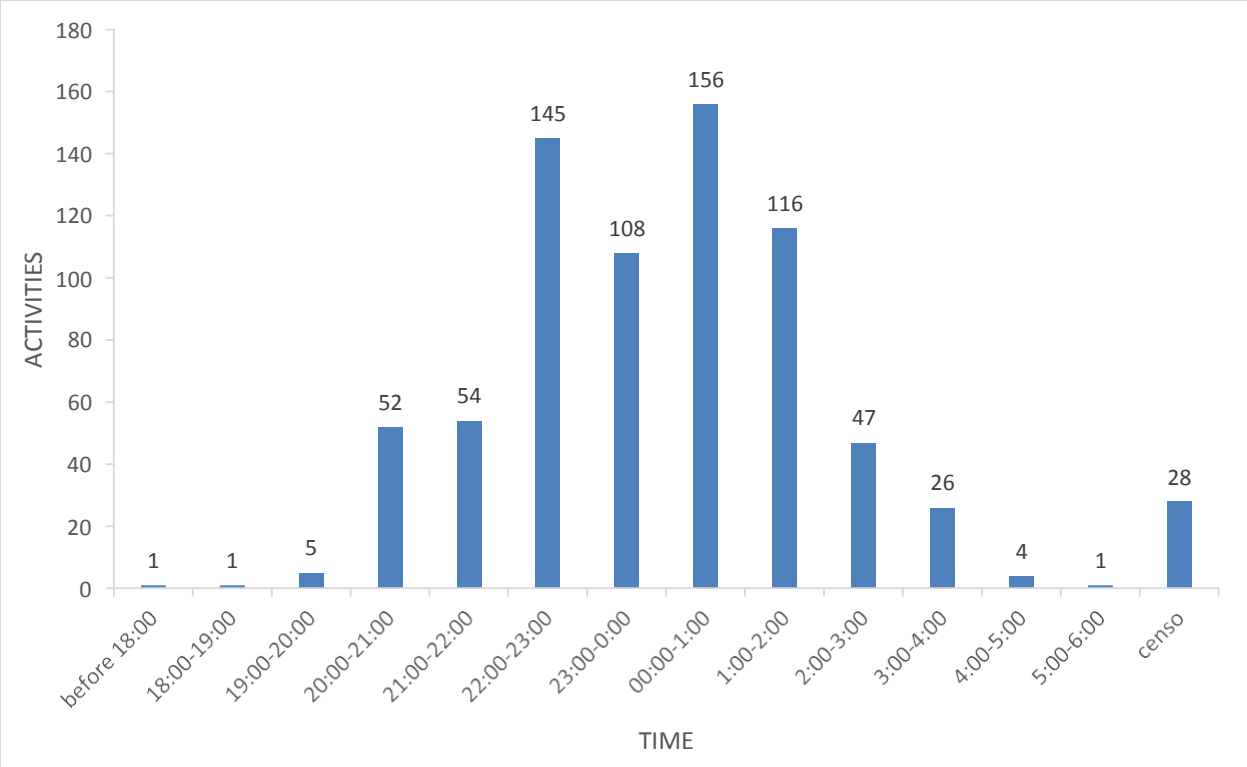

Figure 11. Number of leatherback activities per time interval in 2016.

3.1.4. Stage of Nesting Process

For 62.0% (n=461) of the leatherback activities recorded in 2016, the nightly patrols encountered the turtle during the nesting process (*Figure 12*). For the remaining 38.0% (n=283), the nightly patrols found the tracks without encountering the turtle. Of the 461 encounters with leatherbacks during the nesting process, 23.9% (n=110) resulted in false crawls and 76.1% (n=351) resulted in nests. In 67% of encounters, we found turtles in stages prior to oviposition, which facilitated nest relocation if necessary (*Figure 12*). Most turtles were either digging the egg chamber (27%) or emerging (26%) when encountered by night patrols (*Figure 12*).

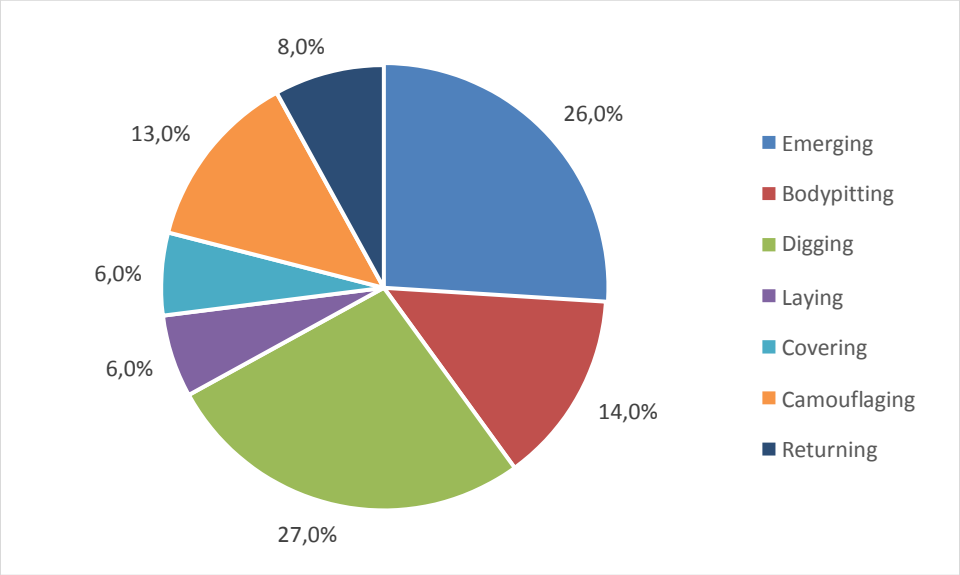

Figure 12. Percent of leatherbacks encountered in each phase of nesting process in 2016 (n=461).

3.1.5. Tagging and Biometric Data

Our tag and recapture program encountered and identified individual leatherbacks on 398 occasions. We identified a total of 204 different females in PNR during the 2016 season. Of these individuals, 90.7% (n=185) had existing tags or evidence of previous tags. The remaining 9.3% (n=19) did not have metal tags, a PIT tag, or any evidence of previous tags when first encountered and were therefore considered neophytes.

Each female laid an average of 2.0 nests. Of the individually identified turtles, 50.7% (n=110) laid only one nest. One of the females tagged at the start of the season was encountered on 6 different occasions, 5 of which resulted in a nest.

We obtained a total of 330 CCL measurements and 329 CCW measurements for 171 different individuals. Average CCL and CCW were 149.8 centimeters and 109.9 centimeters, respectively.

3.1.6. Nesting Success

Of the 744 leatherback activities recorded at PNR in 2016, 58.3% (n=434) resulted in nests (in situ, not confirmed, or relocated), and 41.7% (n=310) did not result in oviposition (did not lay or false crawl) (*Table 2, Figure 13*). Overall leatherback nesting success for 2016 was 58.3%. Of the 434 nests, 59.2% (n=257) were relocated, 10.1% (n=44) were left in situ, and 30.7% (n=133) were not confirmed (*Table 2, Figure 13*). Of the 310 activities that did not result in oviposition, only 8.7% (n=27) were abandoned after bodypitting, and 91.3% (n=283) were false crawls (*Table 2, Figure 13*).

Table 2. Number of leatherback activities of each type per month in 2016.

Month	In Situ	Not Confirmed	Relocated	Did Not Lay	False Crawl
February	0	1	0	0	0
March	11	22	41	1	34
April	23	36	109	4	100
May	8	52	85	13	107
June	2	20	22	8	36
July	0	2	0	1	6
Total	44	133	257	27	283

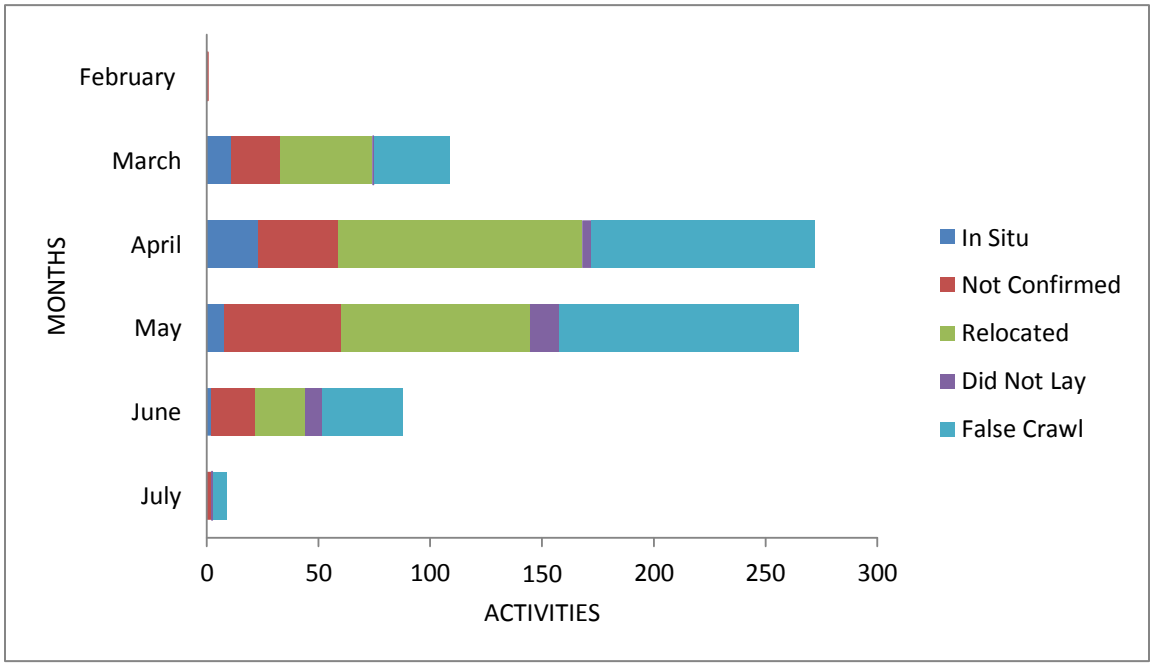

Figure 13. Number of leatherback activities of each type per month in 2016.

3.1.7. Nest Excavation

We excavated 64.3% (n=279) of the 434 nests laid during the 2016 season. We triangulated 69.6% (n=302) of all nests, and we excavated 85.4% (n=258) of triangulated nests. The remaining 14.6% (n=44) were either eroded by the sea, poached, or lost due to triangulation error.

Of the 257 relocated nests, we excavated 86.8% (n=223). The remainder were either eroded by the sea (1.9%, n=5), poached (1.6%, n=4), lost (5.8%, n=15), or excluded because they were part of an experiment conducted by a visiting researcher (3.9%, n=10).

3.1.8. Hatching and Emergence Success

In 2016, average hatching success was 15.7%, and average emergence success was 13.1% (*Table 3*). These values are among the lowest reported by the PNR sea turtle monitoring program, and this was true both for in situ and relocated nests. In situ nests had an average hatching success of 30% and average emergence success of 25% (*Table 3*). Relocated nests had an average hatching success of 12% and average emergence success of 10% (*Table 3*).

Table 3. Leatherback turtle nest contents and success per nest type in 2016.

Nest Type	Eggs	Hatched	Unhatched	Pipped Live	Pipped Dead	Average Hatching Success (%)	Average Emergence Success (%)
In-Situ	4320	1173	2969	27	151	30	25
Relocated	15863	1793	13787	28	255	12	10
Total	20183	2966	16756	55	406	15.7	13.1

We excavated a total of 20183 leatherback eggs, 14.5% (n=2915) of which hatched (*Table 3*). Mean incubation period for leatherback nests was 63 days. Of the 16756 excavated eggs that did not hatch, 55.4% (n=9279) had no visible embryo (undeveloped), and 26.6% (n=4451) had an embryo in the first phase of development (*Figure 14*). The remaining phases of embryonic development accounted for 10.9% (n=1821) of unhatched eggs, and we were unable to identify 7.2% (n=1205) of unhatched eggs (*Figure 14*).

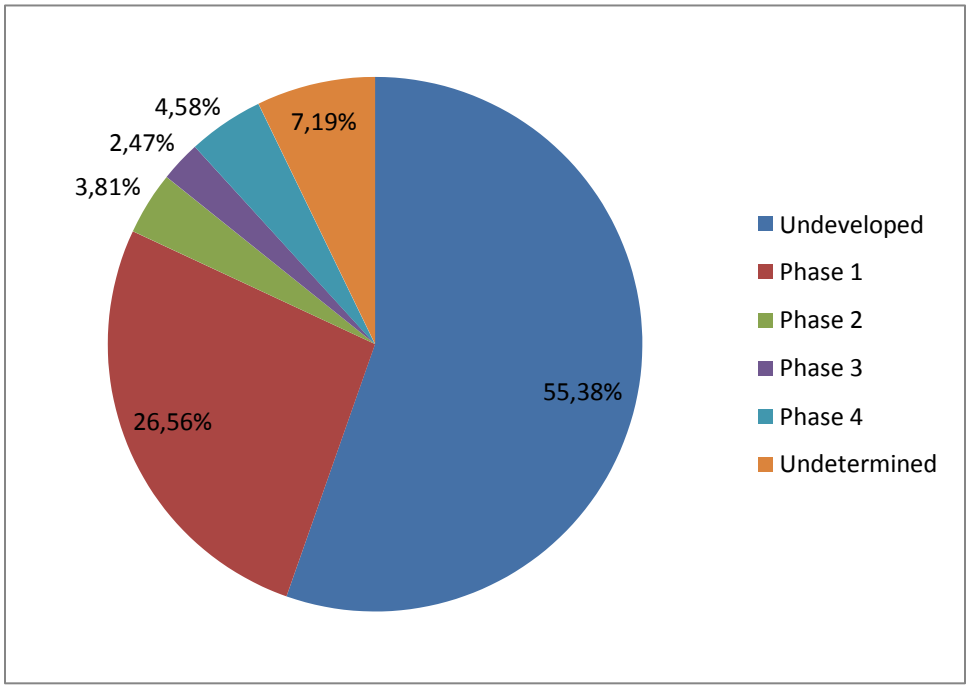

Figure 14. Percent of unhatched leatherback eggs reaching each stage of embryonic development in 2016 (n=16756).

Of the 16756 eggs that failed to hatch, 76.5% were recorded as cooked and 60.8% (n=10189) were affected by fungus (*Table 4*). These were the two most important factors related to egg

failure and mortality in the 2016 nesting season. A relatively small percentage of unhatched eggs were affected by other sources, with only 3.4% (n=573) by roots, 2.8% (n=464) by larvae, 0.96% (n=161) by ácaros, 0.29% (n=49) by crabs.

Table 4. Number and percent of leatherback eggs affected per stage of embryonic development in 2016.

Phase	Total Eggs	Larvae		Cooked		Fungus		Crabs		Roots		Ácaros	
		Total	%	Total	%	Total	%	Total	%	Total	%	Total	%
Undev.	9279	46	0.5	7974	85.9	6638	71.5	0	0.0	243	2.6	47	0.5
1	4451	25	0.6	3243	72.9	2038	45.8	1	0.0	88	2.0	23	0.5
2	639	12	1.9	461	72.1	302	47.3	3	0.5	46	7.2	20	3.1
3	414	23	5.6	290	70.0	239	57.7	0	0.0	28	6.8	9	2.2
4	768	38	4.9	513	66.8	423	55.1	1	0.1	58	7.6	8	1.0
Undet.	1205	320	26.6	335	27.8	549	45.6	44	3.7	110	9.1	54	4.5
Total	16756	464	2.8	12816	76.5	10189	60.8	49	0.29	573	3.4	161	0.96

3.2. Hard-Shelled Turtles

3.2.1. Temporal Distribution

There were 152 nesting activities of hard-shelled turtle species in PNR from May 15th to September 27th, 2016 (*Table 5*). Green turtles accounted for 95.4% (n=145) of hard-shelled turtle nesting activity, and hawksbills accounted for only 4.6% (n=7) (*Table 5*). Green turtle activity was recorded between June 26th and September 27th, and hawksbill activity was recorded from May 15th to September 10th (*Table 5*).

Of the 145 green turtle activities, 80 were false crawls and 65 were nests (*Table 5*). September was the peak of green turtle activity with 36 false crawls and 37 nests for a total of 73 activities (*Figure 15*). This peak corroborates historical data regarding the peak of the green turtle nesting season in the region. Of the 7 hawksbill activities, 1 was a false crawl and 6 were nests (*Table 5*). July was the peak of hawksbill activity with 1 false crawl and 2 nests for a total of 3 activities (*Figure 16*).

Table 5. Number of green turtle and hawksbill activities per month in 2016.

Green Turtle						
Month	**In Situ**	**Relocated**	**Not Confirmed**	**False Crawl**	**Did Not Lay**	**Total**
May	0	0	0	0	0	0
June	1	0	1	0	1	3
July	0	2	7	16	2	28
August	1	1	14	23	2	41
September	0	0	37	33	3	73
Total	2	3	60	72	8	**145**
Hawksbill						
May	1	0	1	0	0	2
June	0	0	1	0	0	1
July	0	0	2	1	0	3
August	0	0	0	0	0	0
September	0	0	1	0	0	1
Total	1	0	5	1	0	**7**
Hard-Shell Total	**3**	**3**	**65**	**73**	**8**	**152**

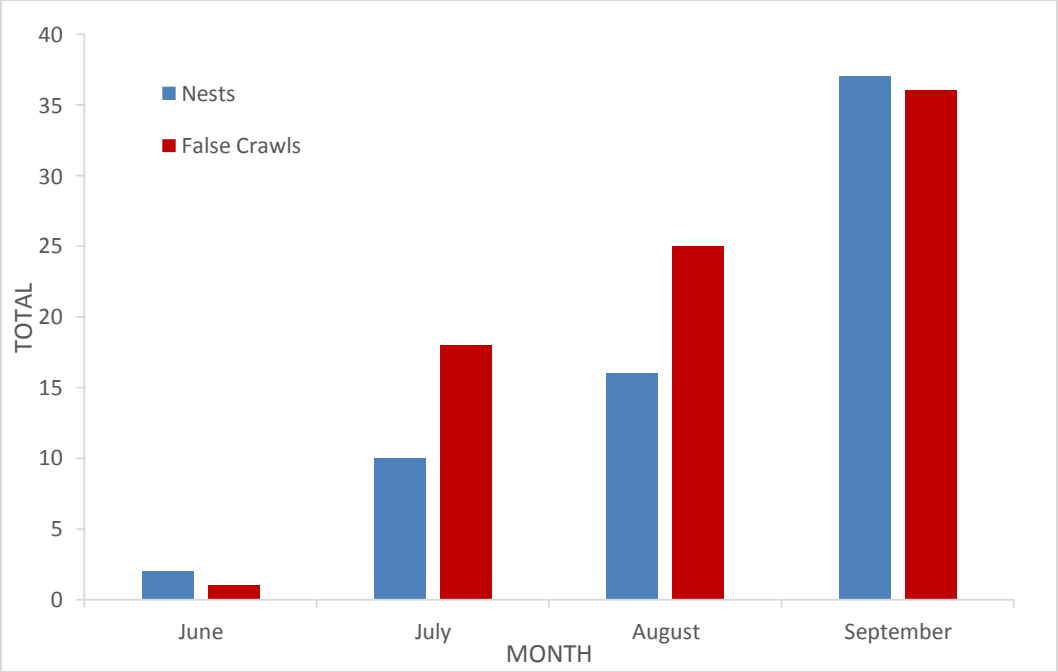

Figure 15. Number of green turtle activities per month in 2016.

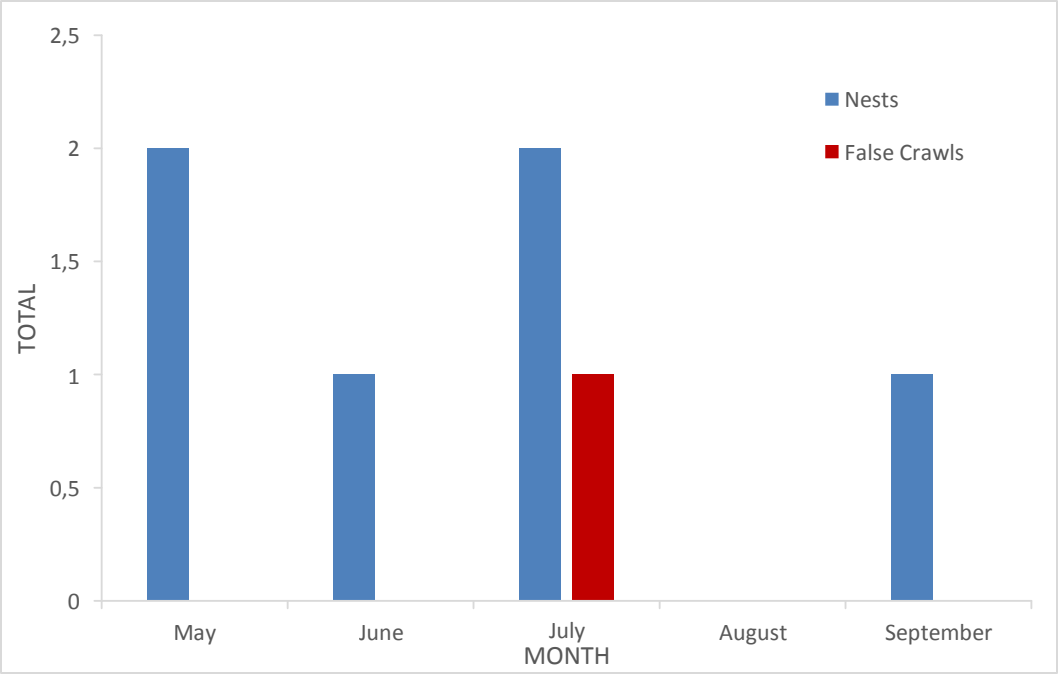

Figure 16. Number of hawksbill activities per month in 2016.

3.2.2. Spatial Distribution

Green turtle and hawksbill activities were evenly distributed over the 5.7-kilometer monitoring area. Sector 30.3 received the most activities, with 3 nests and 2 false crawls (*Figure 17*).

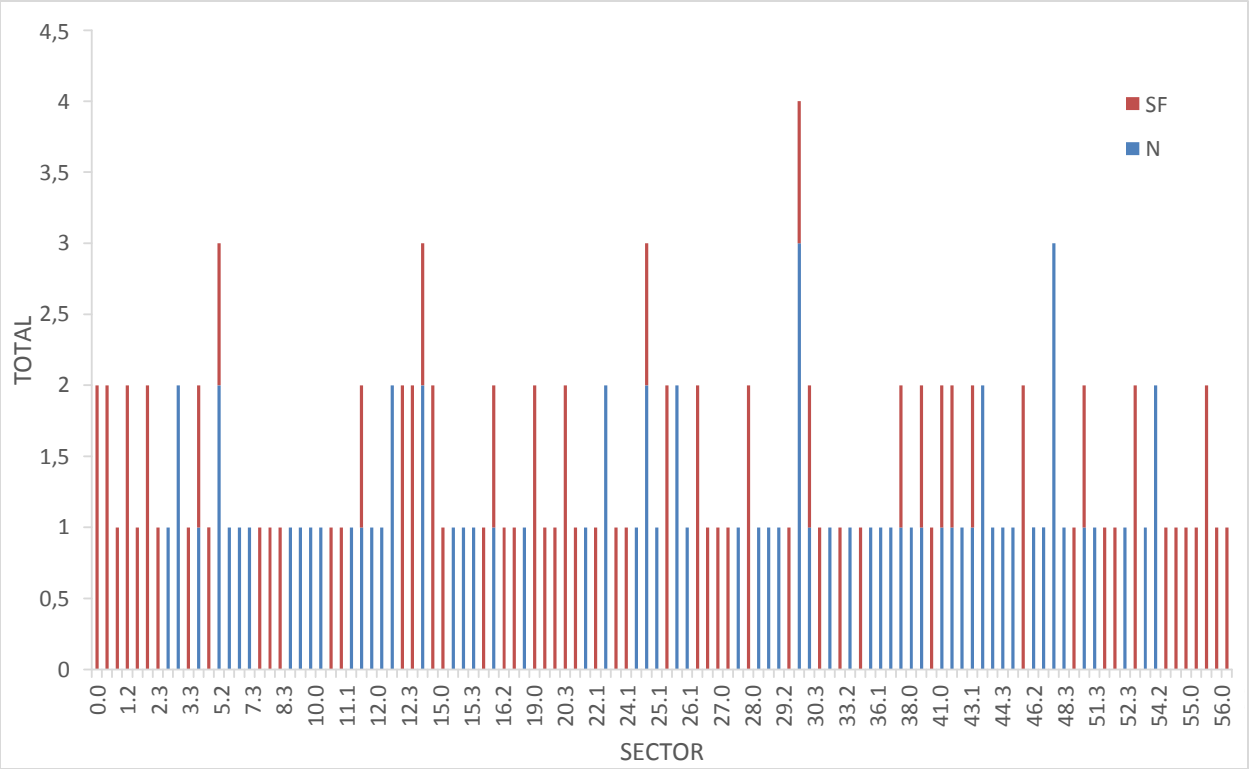

Figure 17. Number of hard-shelled turtle activities per sector in 2016.

3.2.3. Tagging and Biometric Data

Our tag and recapture program identified 7 individual green turtles during the 2016 season. We encountered 2 of these females twice during the season. We encountered and tagged 5 green turtles that we considered to be neophytes because they had no existing tags. Only one of the green turtles we encountered had been previously PIT tagged. We identified 2 individual hawksbills. Both had existing metal tags from Caño Palma, a research station north of Tortuguero National Park. Average green turtle CCL was 101.0 centimeters, and average CCW was 94.9 centimeters. Average Hawksbill CCL was 84.5 centimeters, and average CCW was 78.9 centimeters.

3.2.4. Nesting Success

Of the 152 hard-shelled turtle activities recorded at PNR in 2016, 48.0% (n=73) resulted in nests (in situ, not confirmed, or relocated), and 52.0% (n=79) did not result in oviposition (did not lay or false crawl) (*Table 6*). Overall hard-shelled turtle nesting success for 2016 was 48.0%. Of the 73 nests, 4.1% (n=3) were relocated, 4.1% (n=3) were left in situ, and 91.8% were not confirmed (*Table 6*). Of the 79 activities that did not result in oviposition, only 8.9% (n=7) were abandoned after bodypitting, and 91.1% (n=72) were false crawls (*Table 6*).

Table 6. Number of hard-shelled turtle activities per month in 2016.

Month	In Situ	Not Confirmed	Relocated	Did Not Lay	False Crawl
May	1	1	0	0	0
June	1	3	0	0	0
July	0	11	2	2	16
August	1	14	1	2	23
September	0	38	0	3	33
Total	3	67	3	7	72

3.2.5. Hatching and Emergence Success

We excavated 4 green turtle nests and 1 hawksbill nest for a total of 5 hard-shelled turtle nests. The average emerging and hatching success for hard-shelled turtle nests were both 61.1% (*Table 7*). The average emerging and hatching success for green turtle nests were both 76.4%. Due to the small sample size and the failure of the only hawksbill nest, calculation of these hatching and emerging success values was compromised. We excavated a total of 576 hard-shelled turtle eggs, 55.5% (n=320) of which hatched (*Table 7*). Of the 256 that did not hatch, 70.0% (n=179 had no visible embryo (undeveloped), 3.9% (n=11) were phase 1, 6.6% (n=17) were phase 2, 2.7% (n=7) were phase 4, and 16.4% (n=42) could not be determined (unidentified).

Table 7. Hard-shelled turtle nest contents and success in 2016.

	Eggs	Hatched	Unhatched	Pipped Live	Pipped Dead	Average Hatching Success (%)	Average Emergence Success (%)
Total	576	320	256	1	0	61.1	61.1

4. Discussion

4.1. Leatherback Nesting Trends

The 2016 nesting season had the lowest number of leatherback nests recorded since the monitoring program began in 1994. Historical leatherback nesting data for Pacuare Nature Reserve reveals cycles in which there are distinct four-year peaks in nesting activity (e.g. 1997, 2001, 2005, and 2009) with intervening declines. It is possible that the results of the 2016 monitoring program are related to this nesting population's natural cycles and varying use of other nesting beaches in the region. Continued monitoring of nesting activity at PNR is essential to determining if this is the case. Fluctuating environmental conditions, climate change, and anthropogenic threats in foraging and nesting areas may also impact nesting numbers. Without access to accurate, region-wide data on this nesting population, it is not possible to determine the influence of these factors on nesting activity this season.

4.2. Beach Patrols

Nightly beach patrols succeeded in encountering leatherbacks during the nesting process for 62% of the nesting activities recorded in 2016. To increase the proportion of turtles encountered while nesting, communication between patrol groups is essential and will ensure that patrols cover the beach evenly without leaving large areas of beach unoccupied for extended periods. The participation of PNR station guards is invaluable to the monitoring effort because they provide additional beach coverage near the stations. Guards successfully alerted patrol groups when they encountered turtles and also marked nests for later triangulation or relocation.

4.3. Mark and Recapture Program

In addition to having the lowest number of leatherback nests recorded in 23 years of monitoring, there were few new recruits to the nesting population in 2016. Fewer than 10% of individually identified leatherbacks were neophytes, despite regional trends showing increasing numbers of new females. Continued monitoring of nesting activity at PNR is necessary to determine if this finding is simply part of normal fluctuation in the nesting population.

4.4. Egg Poaching

Four leatherback nests were poached during the 2016 nesting season. Though this is a vast improvement from poaching rates before the monitoring project began, these 4 nests represent nearly 1% of the total number laid during the 2016 season. Despite the best efforts and protection provided by PNR station guards, PNR staff were disturbed on several occasions by people from outside the Reserve walking on the beach at night. It is imperative that the Coast Guard continues to assist with sea turtle protection inside Pacuare Nature Reserve by patrolling the beach and arresting poachers.

4.5. Nest Relocation and Triangulation

Based on the experience of previous seasons at PNR, we relocated nearly 60% of leatherback nests this season due to concerns over severe erosion. However, beach erosion this season was not as severe as anticipated. Additionally, this was an atypically hot and dry season, which negatively affected nests that had been relocated further from the waterline to reduce risk of loss due to erosion. Hatching success of nests left in situ was double the hatching success of relocated nests. Hatching and emerging success might be improved in future seasons by leaving a greater proportion of nests in situ and by relocating nests as close to the original nesting site as possible.

We triangulated nearly 70% of the leatherback nests laid in 2016. This high value reflects both the successful efforts of PNR staff and the unfortunately low nesting numbers this season.

4.6. Eroded and Lost Nests

Beach erosion was responsible for the failure of less than 2% of leatherback nests during the 2016 season. Only 5 nests were eroded, which reflects the success of our relocation program in moving nests away from high-risk erosion-prone areas.

Lost nests were the result of lack of coordination between the patrol leader that marked the nest and the excavation team attempting to recover it and/or measurement error during triangulation. Triangulation techniques should be further emphasized during the intensive training course provided to field assistants at the start of the season.

4.7. Green Turtle Season

There was not a single green turtle poaching event at PNR this season. This is in part thanks to PNR being the only research station in the area that continues to work full time during green turtle nesting season. Poachers likely target areas to the south or north of the Reserve.

Green turtle monitoring at PNR would benefit from efforts to compile and enter green turtle data in a digital database. The digital record of monitoring is incomplete, and efforts need to be made to update and maintain this important record. Regional research efforts and other specialist groups working in the Caribbean would also benefit from the availability of this information, as would the sea turtles we are all working to protect.

Appendix A. Tag Catalog

Tags in bold and highlighted red indicate new tags applied to turtles nesting in Pacuare for the season 2016. If a female was encountered on multiple occasions, we averaged CCL and CCW measurements. We also included the number times we encountered each female during the 2016 nesting season. Of the letters under the column species, DC corresponds to Leatherbacks, CM to Green turtles and EI to Hawksbills.

Species	Left Tag	Right Tag	Removed Tags	Pit Tag	CCL	CCW
DC	AP0023	AP0089		977200095451974	159,5	110,4
DC	VC3526	AP0099	PN3614	905121020518956	168.0	113.0
DC	WC69575	AP0108		985121001002330	151,1	109,9
DC	PN4584	AP0116	AP0115	989001005109795	149,5	114,5
DC	PN2776	AP0120			148,0	108,5
DC	PN4508	ASVO030		985121020545944		
DC	PN2241	CH2696		989001001536899	154,8	111,4
DC	CH6893	CH6894		905120009981802	157,1	111,9
DC	CP1972	CP1974		989001005109765	151,5	109,0
DC	CP2185	CP2184			136,7	102,0
DC	VA1602	O7918			145.5	110.9
DC	WC16802	PM0618		985121020555786	149.0	108.5
DC	PN4551	PM0632		985121020555276	167.6	123.2
DC	PM0696	PM0695		989001005109733	151,0	103,7
DC	PN4554	PM0712		985121020545951	153.6	109.6
DC	PM0959	PM0960		989001005109776	158,0	112,3
DC	WC18090	PM0985		905121020509247	155.5	109.0
DC	PN1368	PN1369			150,0	107,0
DC	PN1706	PN1707		9000118001503310	154,9	108,2
DC	PN1732	PN1733		989001001536904	143,3	108,2
DC		PN1797				
DC	PN2194	PN2195		989001001536944	152,1	117,1
DC	PN2242	PN2243		98900100536872	153.3	109.0
DC	PN2281	PN2283		151538384A	154.0	117.1
DC	PN2355	PN2356		909001001536951	154.9	110.8
DC	VC1457	PN2366		900118001485679	150.3	107.4
DC	PN2386	PN2417		989001005109722		109,8
DC	PN1835	PN2600		98900100536900	148,5	117,5
DC	PN2607	PN2608		989001005109762	155.1	111.9

DC	PN5029	PN2725		900118001505324	152.5	109.5
DC	PN2771	PN2772		989001001536862	154,0	111.5
DC	PN2843	PN2844		900118001506225	155,7	111,8
DC	PN1794	PN2864		989001005109789	142,3	108,2
DC	PN2885	PN2886		989001001536917	154,9	110,8
DC	VC5806	PN2893		989001005109797	157.9	113.7
DC	VC6123	PN3553			143.5	109.2
DC	PN3949	PN3559		989001001536877	147.1	111,0
DC	PN3611	PN3612		989001005109702	148,0	103.5
DC	WC16186	PN3648		9890010015366860	128,0	103.5
DC	WC18941	PN3660		132339453A	150,8	109,7
DC		PN3678			152,5	113,7
DC	VC6126	PN3679		126509692A	155,0	109,0
DC	PN3682	PN3684		989001005109724	154.0	116.0
DC	PM0471	PN3685	PM0472	98900100509800	151,9	110,7
DC	VC6179	PN3706	PN3701	989001001536948	164,0	
DC	PN3721	PN3722		985121020475003	131.0	108.7
DC	VA9869	PN3753		989001001536947	130,5	108,0
DC	PN2319	PN3796	VA7495	989001001536890	149.2	102.5
DC	PN3831	PN3832		909001005109783	148,0	103,3
DC	PN3841	PN3842		989001005109732	145.5	97.9
DC	VA4913	PN3904		989001005109390	152.8	113.0
DC	PN3911	PN3912		989001005109769	141.4	102.3
DC	PN5158	PN3914	PN3774	989001001536876	158,0	105.4
DC	VA4053	PN3915		989001001536930	140.3	104.2
DC	PN2193	PN3916		989001005109792	158.9	111.1
DC	PN2401	PN3918		989001001536953	150,5	101,0
DC	VA4895	PN3934		989001005109714	156.0	113.0
DC	PN1546	PN3950		127239614A		
DC	PN3951	PN3952		989001005109764	142.3	103.2
DC	PN3991	PN3992		909001001536910	155,7	113,4
DC	PN4501	PN4502		AVID*043*038*338*	138,0	105,0
DC	PN1817	PN4507		985121020437029	145,0	110,0
DC	PN4513	PN4514			135.6	100.1
DC	PN4515	PN4516		985121020437480	152,0	114,0
DC	PN4519	PN4520		15142747A	153,3	113,8
DC	PN0659	PN4521			155,0	113,5
DC	PN1724	PN4523		989001001536957	155,2	109,3
DC	PN4535	PN4524		989001005109708	140.0	108.0
DC	PN4529	PN4530				
DC	PN4537	PN4538		989001005109729	142,0	106,0

DC	PN2897	PN4539			157,5	112,3
DC	PN4541	PN4540		989001001536886	145,0	106,0
DC	WC16234	PN4546		985121020520398	155,0	110.2
DC	VC4888	PN4547		909001005109707	130.3	105.7
DC	PN2783	PN4548		989001005109713	157.5	113.5
DC	PN4549	PN4550		989001005109743	139.5	103.0
DC	PN1277	PN4555		989001001095136	158,3	118,4
DC	VC4155	PN4556		AVID*001*597*337	147.0	108.5
DC	PN4561	PN4562			143.3	99.8
DC	PN4563	PN4566		909001005109750	146,1	112,3
DC	PN4567	PN4568		989001005109788	159.9	112.5
DC	PN4569	PN4570		989001005109771	148.3	106,0
DC	PN4573	PN4574		985121020485525	150.0	107.0
DC	PN4575	PN4576	WC16285	989001005103748	140,2	114,5
DC	PN4577	PN4578			154,8	114,2
DC	PN4585	PN4586				
DC	PN4587	PN4588			152.0	113.0
DC	PN4593	PN4594		989001005109758	146.0	108.0
DC	PN4592	PN4598			158.5	115.0
DC	PN5003	PN5004			143.3	103.5
DC	PN2351	PN5005	PN2352	989001005109773	147,0	114.3
DC	PN5021	PN5012		90018001505696	143.2	109.1
DC	PN5009	PN5016			130.5	108,0
DC	PN5023	PN5024		989001005103718	138.5	100.9
DC	WC18997	PN5030			140,0	107,0
DC	PN4505	PN5036	PN4506	132138180A	149.1	110.2
DC	PN5115	Pn5116		989001005109699	154.7	109.1
DC	VA9892	PN5117		151551191A	133,5	106,2
DC	AP0135	PN5133		985121020441766		
DC	PN5159	PN5160		989001005109780	153.3	108.3
DC	PN5173	PN5174	VC6208	989001005103660	153.9	105.3
DC	PN5014	PN5175	PN5013	989001005103721	135,6	100,1
DC	PN5187	PN5188		98900100509734	146.0	109.0
DC	PN5193	PN5194		989001005109735	145.2	102.3
DC	PM0995	VA4091			157,1	112,7
DC	VA4523	VA4524				
DC	VA2576	VA4755		989001005109791	151.9	108.2
DC	VC6103	VA4766		989001001536927	151,0	109.4
DC	PN3933	VA4981			157.5	112.5
DC	WC18015	VA5069		989001005109710	151.1	109.9
DC	VA9379	VA5494		AVID*098*527*550	147.1	111,0

DC	VC3795	VA5860			150.3	112.5
DC	VA7007	VA7080			153.2	113,0
DC	PN2298	VA7649		132827794A	154.2	118.7
DC	WC18033	VA7830			155.7	113.4
DC	VA8985	VA8987		989001005109755	145.0	103.0
DC	VC4515	VA9134		133245797A	144.0	109.1
DC	VA9777	VA9778			130,9	107,0
DC	PN2987	VC0163		151546464A	149.2	108.2
DC	VC0876	VC1171		989001001536951	154,0	108.7
DC		VC1488		985121013044176		
DC	VA8106	VC1604		905121020520488	147.8	114.0
DC	VA8046	VC1615		989001005109736	150.0	113.0
DC	PN5176	VC2050	VC1487	989001005103686	150.0	112.4
DC	WC18699	VC2066		989001005109793	157,0	114,0
DC	VC2117	VC2118			155.0	109.5
DC	VA7008	VC2172		985121020471695	142.7	104,0
DC	PN1602	VC2250		989001001536864	152,0	113,0
DC	VA0870	VC2772		98512102471695	145,0	104,0
DC	VC5813	VC3120		900118001504931	158.2	118.1
DC		VC3279			149.5	114.5
DC	VC1311	VC3369		989001001536928	142.1	102.1
DC	VC3475	VC3476			157.0	107.5
DC	VC6143	VC3486		151542345A		
DC	WC16191	VC3528		989001005109682	157.0	114.0
DC	PN2662	VC3561			154.1	112.5
DC	WC16105	VC3579			151.5	107.5
DC	VC3587	VC3588		989001005109665	151.5	109.5
DC	VC3592	VC3594				
DC	76116	VC3599		985121020475321	154,5	108.2
DC	VC3952	VC3954		989001005109706	142.7	106.5
DC	VC4163	VC4164			147.3	111.7
DC	PN1349	VC4401		985120008740717		
DC	PN1399	VC4404			151,2	106,7
DC	VC4804	VC4905		98900100536918	142.7	106.5
DC	PN3647	VC5725			141.1	105.2
DC	VC5887	VC5888		989001005109716	140.2	114.5
DC	VC5927	VC5928		989001001536954	155,0	109,5
DC	PN2184	VC5952		98900100536866	149,0	117,7
DC	VC5977	VC5978		989001001695123	154.0	109.5
DC	AP0019	VC6034		989001005109751	147,4	106,4
DC	WC16555	VC6076		AVID*081*597*000	157.0	116.5

DC	WC16279	VC6081		9890010015368940	156.2	111.3
DC	VC6095	VC6096		98900100510774	134.6	103.3
DC	VC6109	VC6110		989001005109801		
DC	AP0012	VC6125			153,0	109,7
DC	VC6113	VC6131		985121020549744		
DC	VC6133	VC6134			137.3	97.0
DC	PN1479	VC6139			153,0	107,2
DC	VA4222	VC6180		989001005109766	147.4	108.3
DC	PN4560	VC6197		900118001504554	150.0	113.8
DC	VC5895	VC6222		989001005109719	163,0	113,0
DC	VC6678	VC6680			157,0	112,0
DC	VC6835	VC6840			155,0	109,0
DC	WC16841	WC16200		989001005109790	156.0	110.0
DC	WC16873	WC16811			146.5	102.1
DC	WC16829	WC16816			151.4	105.5
DC	VC1167	WC16843		133209461A	158.5	110.6
DC	PN3505	WC16845			162,0	115.8
DC		WC16878		153547753A	156,3	109,1
DC	PN3903	WC16884			147.3	103.8
DC	WC16917	WC16918			138.2	90.8
DC	PN5157	WC16924	VA5827	989001005109761	142.3	104.5
DC	WC18017	WC18018		151542104A	152.0	114.0
DC	WC18782	WC18549		1273562528	154,7	111,2
DC	WC18605	WC18606		989001001536870		
DC	WC18609	WC18610			143,5	109,2
DC	WC18615	WC18616		985120009986856	154,8	108,9
DC	PN2586	WC18644		989001005109799	152.1	110.5
DC	WC18641	WC18677		9851210008743730	152,0	109,0
DC	VC1117	WC18678		132136386A	143.4	106.2
DC	WC18689	WC18688		989001005109767	152,7	115,0
DC	WC18690	WC18691		989001005109728	151,5	107,5
DC	WC18749	WC18750		AVID*043*047*049	153,6	113,8
DC	WC18931	WC18932			155,0	110,2
DC	WC18938	WC18937		989001005109717	155,0	111,9
DC	WC18939	WC18940			157,0	116,5
DC	WC18943	WC18944		151546411A		
DC	WC18989	WC18990			151,4	105,5
DC	WC18993	WC18994			143,3	99,8
DC	WC18995	WC18996			151,3	106,1
DC	AP0119				148,7	105,2
DC	PN2221					

DC	PN2935			AVID*045*615*879	146,8	108,4
DC	PN4572			127113572A		
DC	PN5125				155.0	111.0
DC	VC1869					
DC	VC3458				156.3	109.1
DC	VC6151				152,0	109,0
DC	WC18988				157.0	120.3
DC				98512102485525	149,0	105,0
DC				98900100536447		
DC				989001005109725		
DC				133245791A		
CM	PN3111				98.7	87.5
CM	PN0849	PN0850			95,3	91,2
CM	VC1922	WC18754				
CM	VC5895	VC6222		989001005109719		
CM	PN3194	PN3195				
CM		PN0921				
CM	PN0915	PN0904				
EI	CP2876	CP2874			82,0	92.2
EI	CP2256	CP2255			87	65.5