Leatherback Turtle, Dermochelys coriacea, Hatching Success at Jamursba-Medi and Wermon Beaches in Papua, Indonesia

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ABSTRACT. – Hatching success for leatherback turtles (Dermochelys coriacea) was low at 4 important nesting beaches in Papua, with high rates of tidal inundation, pig predation, and possible temperature effects. Better protection from pigs and possible nest relocation may be needed to improve hatching success for leatherbacks.

Leatherback turtle (Dermochelys coriacea) populations in the Pacific have witnessed a dramatic decline in nesting numbers in the past few decades (Spotila et al. 2000). Nevertheless, while nesting numbers on beaches in the eastern Pacific and Malaysia (Chan and Liew 1996) have plummeted, Jamursba-Medi and Wermon beaches in Papua, Indonesia, host one of the last major nesting beaches for leatherbacks in the Pacific (Hitipeuw and Maturbongs 2002; Suganuma 2006; Hitipeuw et al. 2007). Monitoring work in Papua has focused less on hatchlings, occasional evaluations of hatching success and factors impacting nests (Bhaskar 1987; Hitipeuw and Maturbongs 2002; Suganuma et al. 2005; Suganuma 2006), as well as discussions with local communities have suggested low hatching production, especially on Jamursba-Medi. Predation by pigs, dogs, and lizards; collection of eggs by the local people; and beach erosion and inundation have been reported to lower the number of hatchlings produced (Bhaskar 1987; Stark 1993; Starbird and Suarez 1994; Maturbongs 2000; Hitipeuw and Maturbongs 2002; Suganuma et al. 2005; Suganuma 2006; Wurlianty and Hitipeuw 2006; Hitipeuw et al. 2007).

Given the observed decline in Pacific leatherbacks and the importance of the Papuan nesting population, identifying factors that impact hatching is crucial for developing wise management strategies to boost hatching production in Papua. Therefore, an in-depth evaluation of hatching production was initiated in 2005. The objectives of this preliminary study were to estimate hatching success on the different beaches and evaluate some factors that may affect hatching success, such as nest destruction by nesting females, predation, inundation, erosion, and sand temperature. The study was conducted during the 2005 nesting season in Jamursba-Medi and the 2006 nesting season in Wermon.

Methods. — Jamursba-Medi beach spans 18 km of coastline and includes 3 beaches: Warnamedi (ca. 4.8 km), Batu Rumah (ca. 5 km), and Wembrak (ca. 8.2 km), from east to west (Hitipeuw et al. 2007). The sand color varies across the 18 km from white/light gray sand on Warnamedi to dark gray/black sand on Wembrak. Nesting at Jamursba-Medi takes place between March and September (Hitipeuw and Maturbongs 2002). Approximately 30 km east of Jamursba-Medi lies Wermon, a 6-km-long nesting beach with dark gray sand; leatherback nesting on this beach occurs primarily between October and March (Hitipeuw et al. 2007).

To evaluate factors affecting hatching success, 100-m-long plots, or sections of beach, were randomly selected at Jamursba-Medi (6 Wembrak, 3 Batu Rumah, and 4 Warnamedi) in May 2005 and at Wermon (n = 6) in January 2006. To determine whether water levels in the beach rose high enough to drown nests, 150-cm-long PVC pipes, 10 cm in diameter, were placed to a depth of 140 cm. In a randomly selected subset of 7 plots in Jamursba-Medi, 1 pipe was placed in the lower, open section of the beach (= lower zone) and 1 pipe was placed within 4 to 5 m on average of the vegetation line (= upper zone) of each plot. In Wermon, pipes were placed in the upper and lower zones of all 6 plots. Data loggers (HOBO Water Temp Pro, –20° to 70°C) were buried in the sand at a depth of 70 cm, estimated to be the average depth of leatherback nests based on consultations with local patrollers in the absence of data, at approximately 50 cm from the pipe and programmed to record sand temperature every hour. Every morning, the locations of new nests (= distance of the nest from the vegetation line and the ends of the plot) were determined by experienced local patrollers and marked.
with a stake. The number of marked nests depredated, eroded, washed over by high tide, and/or dug up by nesting leatherbacks was noted. Twice a week, the water level was checked in the pipes and plot width was measured from the vegetation line to the most recent high-tide mark from the east, west, and 50-m midpoint of each plot and averaged to evaluate available nesting area.

In Jamursba-Medi, data were collected daily between 30 May 2005 and 26 July 2005, the peak nesting months; sand temperatures were recorded between 1 June 2005 and 27 August 2005. At Wermon, data were collected daily between 27 January 2006 and 8 April 2006; pipes were placed in the beach at the end of February. Sand temperatures were recorded between 1 February 2006 and 19 April 2006 in Wermon. At both beaches, nests were excavated after the main hatching emergence had been observed or after approximately 75 days of incubation. A nest inventory was done and clutch size was determined by counting eggshells ≥50% intact and the unhatched eggs; only eggs containing yolk were used to determine clutch size. Hatching success was calculated by dividing the number of eggshells ≥50% intact by the clutch size. The distance from beach surface to the top of eggs as well as to the bottom of the nest was also recorded during nest excavations. No inventory was done of depredated nests because pigs—the primary predators—appeared to consume the entire clutch. Incubation time—i.e., time between clutch deposition and hatching emergence—was calculated only when the date of hatching emergence had been noted. To avoid including potentially incomplete clutches, only clutch sizes with 40 or more eggs were incorporated in the analyses.

Mean values for clutch size, nest measurements, and incubation period were determined for Jamursba-Medi and Wermon. The percentage of nests dug up by nesting females, depredated by pigs, and washed over by high tides on both beaches or lost to erosion was also estimated. The impact of groundwater level on incubating nests was evaluated. Sand temperature data were averaged over the study period for each data logger, and temperatures in the upper and lower zones at Jamursba-Medi and Wermon were compared using a paired t-test and Wilcoxon signed ranks test, respectively. To determine whether sand temperatures varied among months at Jamursba-Medi and Wermon, temperatures were averaged for each month for each data logger and compared among months using an analysis of variance (ANOVA) test followed by the Scheffe’s pairwise comparison test. Overall sand temperatures were compared between Jamursba-Medi and Wermon using a Mann-Whitney test. Hatching success was compared among the 3 beaches in Jamursba-Medi and among the plots in Wermon using Mann-Whitney tests and ANOVA, respectively; hatching success values were also compared between Jamursba-Medi and Wermon using the Mann-Whitney test. If assumptions of normality and equal variance were violated, nonparametric tests were used (Wilcoxon signed ranks test and Mann-Whitney test). For all variables, equality of variances was tested using a Levene’s test, and normality of data was determined by a Kolmogorov-Smirnov test. Data were analyzed using SPSS 14.0 and Minitab 13.0. Alpha level was set at 0.05.

Results and Discussion. — The mean values for clutch size, distance from beach surface to top of eggs, nest depth, and incubation period at Jamursba-Medi and Wermon are presented in Table 1.

No nests were destroyed by nesting females at Jamursba-Medi or Wermon. The mean number of nests laid in the 100-m–long plots was 9 (SD = 4.7, n = 6) in Wembrak, 7.3 (SD = 5.9, n = 3) in Batu Rumah, approximately 24.8 (SD = 13.7, n = 4) in Warmanedi, and 15.2 (SD = 8.0, n = 6) in Wermon. Average plot area was 3070 m² in Wembrak, 2930 m² in Batu Rumah, 3340 m² in Warmanedi, and 1760 m² in Wermon. Therefore, the probability of a female digging up another nest while nesting was relatively low. The local patrolers, recruited from the villages on the beach, indicated that this had been a more common occurrence in the past at Jamursba-Medi—likely because nesting numbers were much higher then (Hitipeuw et al. 2007).

Pig predation in Jamursba-Medi during June and July 2005 occurred primarily in Warmanedi (n = 29 nests; around 29.3% of the nests laid during this period), with only 1 depredated nest in Wembrak (n = 29 nests; around 33% of the nests laid during this period), with only 1 depredated nest in Wembrak. Later observations in September and October confirmed extensive predation by feral and domestic pigs at Warmanedi. Past studies have also reported a large number of nests destroyed by pigs (Stark 1993; Hitipeuw and Maturbongs 2002; Suganuma 2006). Presently, to control pig predation in Jamursba-Medi, domestic pigs have been removed from the beach, and an electric fence (Suganuma 2006) as well as a barbed-wire fence have been installed to deter feral pigs. A combination of barbed-wire fences and pig traps along the beach is also being considered. Because the local people hunt pigs for consumption, pig traps on the beach would greatly benefit those participating in the sea turtle monitoring project.

### Table 1. Mean clutch size, nest measurements, and incubation period from Jamursba-Medi and Wermon (Nest top = distance from sand surface to the top of eggs; Nest bottom = distance from sand surface to the bottom of the nest).

<table>
<thead>
<tr>
<th></th>
<th>Jamursba-Medi mean (SD) range</th>
<th>Wermon mean (SD) range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clutch size</td>
<td>79.6 (16.3) 48 (40–106) n = 51</td>
<td>76.2 (16.1) 51 (41–109) n = 51</td>
</tr>
<tr>
<td>Nest top (cm)</td>
<td>71.6 (12.2) 49 (30–101) n = 51</td>
<td>71.1 (9.6) 51 (49–98) n = 51</td>
</tr>
<tr>
<td>Nest bottom (cm)</td>
<td>91.3 (13.3) 48 (37–119) n = 51</td>
<td>85.1 (9.9) 51 (62–114) n = 51</td>
</tr>
<tr>
<td>Incubation period (days)</td>
<td>61.5 (4.7) 13 (54–70) n = 38</td>
<td>61 (5.1) 38 (56–74) n = 49</td>
</tr>
</tbody>
</table>

Nest measurements: Nest top = distance from beach surface to top of eggs; Nest bottom = distance from sand surface to the bottom of the nest.


No predation was observed in Wermon between January and April 2006. During the 2003–2004 season, approximately 4.9% and 3.9% of the nests were depredated by pigs and dogs, respectively (Hitipeuw et al. 2007); no lizard predation was observed. Between November 2004 and September 2005, pigs, dogs, and lizards were responsible for depredating 10.6%, 10.1%, and 0.5% of the nests in Wermon, respectively (Wurlianty and Hitipeuw 2006). Suganuma et al. (2005) estimated that dogs and lizards had destroyed 13.1% and 4.4%, respectively, of the 460 nests recorded between January and February 2005. A study by Starbird and Suarez (1994) indicated that fewer than 40% of the nests were depredated by pigs at Wermon; increased hunting by the villagers may be reducing the local pig population (Hitipeuw and Maturbongs 2002).

In Jamursba-Medi, high tides in July washed over 31.5% (n = 17) of the nests in Wembrak and around 15.2% (n = 15) of the nests in Warmamedi; the high-tide line lay below the nests in Batu Rumah. Observations indicated that by October, much of the beach at Wembrak and Warmamedi was washed over by high monsoon tides, but some plots in Batu Rumah remained secure. Despite its stability, Batu Rumah supports the lowest nesting numbers (Hitipeuw et al. 2007).

In Wermon, approximately 9% (n = 8) of nests laid in the plots were washed away by high tides. Similarly, between November 2003 and May 2004, 9% of nests were estimated to have been washed away by tides in Wermon (Hitipeuw et al. 2007). However, between November 2004 and September 2005, 23% of nests were inundated by tidal activity (Wurlianty and Hitipeuw 2006). No nest loss to erosion was observed during the study period at either beach. Beach erosion is extensive in Jamursba-Medi after the peak nesting period, potentially impacting many nests (Hitipeuw et al. 2007); erosion has been observed to be less pronounced in Wermon. Further evaluation of beach dynamics on hatchling output is necessary. No water was recorded in the pipes on either beach during the study period.

At Jamursba-Medi, sand temperatures fluctuated between 28.6°C and 34.9°C (Table 2). No difference in mean temperature occurred between the upper and lower zones of the beach (paired t-test; t = −0.59, p = 0.58, n = 7). However, mean sand temperatures differed among months (ANOVA; F = 4.83, p < 0.001), with temperatures in July being significantly lower than June and August (Scheffe’s; p = 0.001). Although temperatures could not be statistically compared among Wembrak, Batu Rumah, and Warmamedi because of small sample size, the average temperatures recorded tended to be highest in Wembrak and lowest in Warmamedi (Table 2), reflecting the variation in sand color. In Wermon, observed sand temperatures fluctuated between 27.0°C and 32.7°C (Table 2). No difference in mean temperature was found between the upper and lower zones of the beach (Wilcoxon signed ranks test; p = 0.14), or among months (ANOVA; F = 0.18, p = 0.83).

A comparison of mean sand temperatures between Jamursba-Medi and Wermon indicated that overall temperatures were lower in Wermon (Mann-Whitney test, p = 0.03, Table 2). Despite having black sand, Wermon sand temperatures are probably lower because the nesting season coincides with the monsoons. Additionally, both beaches are backed by tropical rainforest, and differences in the amount of shade provided by the forest may play a role in lowering sand temperature, however, this aspect was not evaluated in this study. The warmer range of temperatures at Jamursba-Medi and the lower range of temperatures at Wermon may produce more females at Jamursba-Medi and more males at Wermon, but a more in-depth study is required to determine the sex ratio contribution of each beach.

Hatching success in nests undisturbed by pig predation was significantly lower in Jamursba-Medi than in Wermon (Jamursba-Medi: mean = 25.5%, SD = 32%, range = 0%–85%, n = 48; Wermon: mean = 47.1%,

<p>| Table 2. Average sand temperature (°C) at 70 cm in the lower and upper beach zones recorded from 1 Jun 2005 to 27 Aug 2005 in Jamursba-Medi (Wembrak, Batu Rumah, and Warmamedi) and from 1 Feb 2006 to 19 Apr 2006 in Wermon (lower zone = lower, open section of the beach; upper zone = within 4 to 5 m on average of the vegetation line). |</p>
<table>
<thead>
<tr>
<th>Wembrak mean (SD) (range)</th>
<th>Batu Rumah mean (SD) (range)</th>
<th>Warmamedi mean (SD) (range)</th>
<th>Wermon mean (SD) (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower zone</td>
<td>Upper zone</td>
<td>Lower zone</td>
<td>Upper zone</td>
</tr>
<tr>
<td><strong>Jun 2005</strong></td>
<td><strong>32.5 (1.04)</strong></td>
<td><strong>32.7 (1.1)</strong></td>
<td><strong>31.6 (0.9)</strong></td>
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<tr>
<td>(30.6–34.7)</td>
<td>(30.6–34.7)</td>
<td>(29.8–33.4)</td>
<td>(30.6–34.9)</td>
</tr>
<tr>
<td><strong>Jul 2005</strong></td>
<td><strong>31.3 (0.5)</strong></td>
<td><strong>31.4 (0.7)</strong></td>
<td><strong>30.7 (0.7)</strong></td>
</tr>
<tr>
<td>(30.2–33.1)</td>
<td>(29.7–32.6)</td>
<td>(29.4–32.5)</td>
<td>(30.1–32.6)</td>
</tr>
<tr>
<td><strong>Aug 2005</strong></td>
<td><strong>33.1 (0.7)</strong></td>
<td><strong>33.2 (0.9)</strong></td>
<td><strong>32.3 (1.1)</strong></td>
</tr>
<tr>
<td>(31.4–34.6)</td>
<td>(31.2–34.9)</td>
<td>(30.5–34.3)</td>
<td>(31.0–34.6)</td>
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<td><strong>Feb 2006</strong></td>
<td>—</td>
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<td><strong>Mar 2006</strong></td>
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<td><strong>Apr 2006</strong></td>
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</table>
ANOVA; did not differ significantly among plots in Wermon (ANOVA; $F = 9.57$, $p > 0.05$). The thermal tolerance range for sea turtle embryos is estimated to lie between 25°C and 35°C (Ackerman 1997) or between 24°C and 32°C (Yntema and Mrosovsky 1982), and the pivotal temperatures tend to cluster around 29°C (Mrosovsky 1994). High sand temperatures at Jamursba-Medi, especially in Wembrak, may be potentially exceeding the thermal tolerance of these leatherback embryos, resulting in the high embryo mortality observed in clutches; mean observed embryo mortality in a clutch at Jamursba-Medi was 33.3% (SD = 26, range = 0%–92.3%, $n = 47$). Lower sand temperatures at Wermon could possibly be one of the factors contributing to a higher probability of egg survival. However, a far more thorough evaluation of factors such as stage of mortality during development, duration of exposure to recorded temperatures, and thermal tolerance of leatherback embryos in Papua is required before any conclusions can be made on the impact of sand temperature on hatching success in Papua. Additionally, greater inundation of nests at Jamursba-Medi than at Wermon may also lower hatching success on the former beach, although this could not be evaluated in this study. Low hatching success is characteristic of leatherbacks despite high fertility rates (reviewed in Bell et al. 2003), and may result from a complex interaction between egg position and its microenvironment (Wallace et al. 2004).

In the past, mean hatching success estimates from Jamursba-Medi have varied from 20.1% to 77.1% (Bhaskar 1987; Hitipeuw and Maturbongs 2002; Suganuma 2006). However, these hatching success results need to be viewed with caution because the sample size was often very small and/or the methodology was often unclear and could possibly have been biased towards nests observed to hatch. In Wermon, 12 of 32 nests did not hatch during a 1994 study (Hitipeuw and Maturbongs 2002). Suganuma (2006) reported a very low mean hatching success of 6.8% ($n = 51$) from Wermon in 2005, caused possibly by high waves washing over the nests.

In conclusion, any management plan developed for Papua will need to address the impact of predation, inundation, and beach erosion. Studies on the impact of sand temperatures on embryo mortality and a spatial and temporal evaluation of erosion and nest loss are much needed to develop a good management strategy. Nest relocation to potentially cooler sections of the beach above erosion zones and tidal activity or to shaded or irrigated hatcheries where temperature is monitored may become essential to ensure greater hatching output, especially at Jamursba-Medi. Results of a preliminary hatchery experiment indicate that in a shaded hatchery, mean hatching success can be increased considerably to 70.5% (SD = 30.8, range = 0%–96.4%, $n = 15$; Tapilatu and Tiwari, unpubl. data). Predation, especially by pigs, will need to be controlled through an effective combination of fence and animal traps to deter animals from accessing nests. Monitoring of the spatial and temporal variability in hatching success and factors affecting hatching production over entire nesting seasons will need to continue as management strategies are devised and refined to ensure greater hatching input into the Papuan leatherback population. Finally, involvement of the local people is crucial to the success and persistence of this nesting population.

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LITERATURE CITED


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