Biodivers Conserv
DOI 10.1007/s10531-014-0682-x

ORIGINAL PAPER

The value of endangered species in protected areas at risk: the case of the leatherback turtle in the Dominican Republic

Ohiana Revuelta · Yolanda M. León · Juan A. Balbuena · Annette C. Broderick · Pablo Feliz · Brendan J. Godley · Juan A. Raga · Jesús Tomás

Received: 18 July 2013 / Revised: 7 March 2014 / Accepted: 19 March 2014

Abstract Protected areas are considered essential elements for global biodiversity conservation. They may not necessarily result in an effective conservation of resources in developing countries due to lack of funding for management and enforcement. In addition, poor governance aligned with conflicts of economic interests related to their use can further threaten their integrity and persistence. In the Dominican Republic, the western beaches of the Jaragua National Park (JNP), a protected area which is also part of a UNESCO Biosphere Reserve, have been proposed for development using a mass-tourism model. One of the most charismatic species found in this area is the leatherback turtle (*Dermochelys coriacea*). In the present study, we assess hatching success, and factors affecting it, to determine the reproductive value across the area for the leatherback turtle. The main factors found driving hatching success at the study beaches are beach sector, incubation duration, date of lay and clutch size. Our results show that clutches in La Cueva (located in the buffer zone of the park) and Bahía de las Águilas (located inside the limits of the park) have an unusually high hatching success ($\sim$75 %) for this species, highlighting the importance of increasing protection efforts at these sites. We strongly recommend including La Cueva inside the limits of the JNP.

Communicated by Margaret Miller.

O. Revuelta (✉) · J. A. Balbuena · J. A. Raga · J. Tomás
Cavanilles Institute of Biodiversity and Evolutionary Biology, Science Park, University of Valencia, P.O. Box 22085, 46071 Valencia, Spain
e-mail: ohiana.revuelta@uv.es

Y. M. León · P. Feliz
Grupo Jaragua, El Vergel 33, El Vergel, Santo Domingo, Dominican Republic

Y. M. León
Instituto Tecnológico de Santo Domingo, Ave. de los Proceres, Urb. Galá, Santo Domingo, Dominican Republic

A. C. Broderick · B. J. Godley · J. Tomás
Centre for Ecology and Conservation, College of Life and Environmental Sciences, University of Exeter, Cornwall Campus, Penryn TR10 9EZ, UK

Keywords *Dermochelys coriacea* · Hatching success · Conservation · Protected areas · Dominican Republic

Introduction

Protected areas remain a cornerstone of global conservation efforts to preserve diminishing wildlife species and their habitats (CBD 2010; Butchart et al. 2012). In the Caribbean, the establishment of marine protected areas (MPAs) to protect natural resources, unique habitats and threatened species have proliferated over the last few decades (Guarderas et al. 2008). Nevertheless, in many countries not all protected areas have management plans, and when they exist, the national authorities responsible for their protection are often under-resourced, making protection less effective (e.g. Ervin 2003; Buitrago et al. 2008).

The Dominican Republic (DR) is a developing country experiencing a rapid increase in international tourism, particularly focussed on coastal areas of the north and southeast regions (León 2007; Wielgus et al. 2010). In recent years, this mass-tourism model and the expansion of existing bauxite and limestone mining have been proposed as valuable ways to enhance the impoverished economy of the southwest of the country (Wielgus et al. 2010). It is known that these activities could result in an adverse impact on natural environments such as pollution and sand mining, with detrimental effects on reefs and seagrass ecosystems (Geraldes 2003; Grandoit 2005).

At the southwest of the country, the Bahía de las Águilas hosts one of the last refuges of coastal marine fauna and flora available to the DR. The ecosystems are thought unlikely to be able to support mass tourism (Wielgus et al. 2010). This area has unique vegetation with several endemic plants and, among its marine ecosystems, there are the most extensive and best preserved seagrass beds in the country. Coral reefs are found a short distance from the coast, so it is highly probable that these reefs would be greatly affected by any land-based pollution, particularly resultant from mining activity. Finally, the bay hosts reproductive areas of Rhinoceros iguana (*Cyclura cornuta*) and marine turtles (Rupp et al. 2005; Revuelta et al. 2012).

One of the most charismatic species in this area is the leatherback turtle (*Dermochelys coriacea*). Although populations of this species seem to be recovering in the North Atlantic, and it has assigned to be under “low risk and low threat” (Wallace et al. 2011), in some rookeries this species faces serious threats, such as egg take that compromise their conservation (e.g., Patiño-Martínez et al. 2008). Moreover, the leatherback turtle exhibits what is considered a very low hatching success rate ($\sim$50 %) in comparison to other marine turtle species (Bell et al. 2003; references in Eckert et al. 2012).

In the past, the leatherback turtle was reported nesting widely around the coast of the DR (Ottenwalder 1981), but today the last important nesting areas for the species are located in the beaches of the Jaragua National Park (JNP; Revuelta et al. 2012). There are two leatherback nesting areas in the Park, the beaches adjacent to the Oviedo lagoon at the east, which experienced 100 % egg take by local people, and Bahía de las Águilas and La Cueva beaches in the west of the Park (Revuelta et al. 2012), but La Cueva is only currently within the buffer zone of the Park (see study site section). Since 2006, a cooperative marine turtle conservation project has been carried out at the JNP and, as a result, leatherback clutches are currently monitored for protection by rangers at the western nesting beaches. However, the strong pressure to bring mass tourism to these beaches in the form of high capacity resorts represents a potential threat to protected fauna of the Park (Rupp et al. 2005) including nesting marine turtles. The JNP was created in 1983 and since 2002 it has been part of the UNESCO Jaragua-Bahoruco-Enriquillo Biosphere Reserve. Multiple national laws as well as international agreements ratify protection for the Bahía de las Águilas territory and/or its natural resources: The General Environmental Law 64-00, the Sectorial Law for Protected Areas 202-04, The Convention on Biodiversity, and The Cartagena Protocol for Wildlife Areas with Special Protection. In Bahía de las Águilas, building and extraction of animals or plants are prohibited, but visits of tourists by boat or by 4 $\times$ 4 vehicles into the beach are permitted. A ranger post is placed at the entrance of the bay, and rangers patrol the beach regularly. In the buffer zone of the park there is no patrolling and access to the beach is uncontrolled.

Here we set out (1) to study hatching success and factors affecting it to determine the reproductive value across the area for the leatherback turtle and, (2) to ascertain the importance of both nesting beaches for this threatened species to reinforce conservation in the face of anthropogenic threats at site.

Methods

Study site

The present study was conducted between 2007 and 2010 at the western beaches of The JNP (N17°57′, W71°39′) a protected area of 1,374 km^2 (of which 905 km^2 is marine reserve) situated in the south-western corner of the DR (Fig. 1). Bahía de las Águilas is a 4.4 km sandy bay located inside the park but is also considered as a national recreational area according to local laws and is frequented by several thousand Dominican and international tourists per annum. La Cueva beach (2.5 km in length) is located in the northern buffer zone of the park. A small village (around 20 inhabitants) and a rangers' post are located between these two beaches that are separated by a rocky zone of 1 km length.

Data collection

During the leatherback nesting season (from March to August, with a peak in April–June), we carried out night and daytime surveys at Bahía de las Águilas and La Cueva nesting beaches (see Revuelta et al. 2012 for an exhaustive description). When we found a clutch, we camouflaged the tracks of females and recorded GPS coordinates; we also recorded distance from nest to high tide line, the beach sector (Bahía de las Águilas and La Cueva) and the zone of the beach where the clutch was located (open sand, or within the dune vegetation).

We studied a total of 109 clutches laid on the beaches of Bahía de las Águilas and La Cueva over four nesting seasons (2007–2010). We excavated clutches by hand one to three days after hatchling emergence was detected. Clutch size was defined as the total number of eggs (hatched and unhatched yolked eggs) clutch^{-1}. Hatching success was calculated by dividing the number of eggs hatched by the clutch size, expressed as percentage (Miller 1999). Leatherback turtle clutches have a high frequency of eggs without yolk commonly referred as yolkless eggs which were also counted during the excavation but were not included in clutch size.

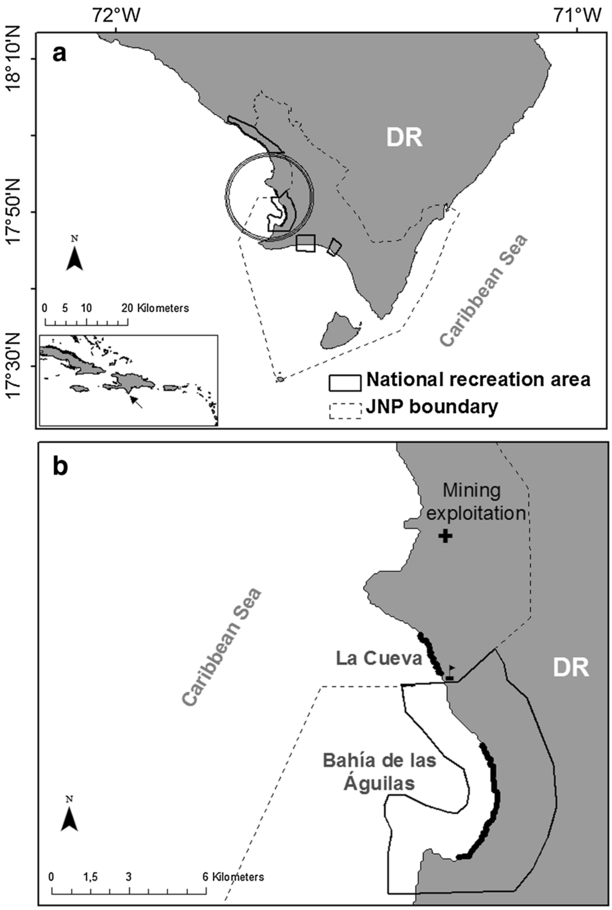

Fig. 1 **a** Map of the JNP (SW DR) showing the park limits and the areas of recreational use inside it. The *insets* indicate the location of the main maps in the Caribbean. The *circle* indicates the area enlarged in **b**. **b** Leatherback nesting beaches at the West of the Park, Bahía de las Águilas and La Cueva

Statistical analysis

We undertook detailed data exploration before any statistical analysis following Zuur et al. (2010). When the underlying question is to determine which covariates are driving a system, the most difficult aspect of the analysis is probably how to deal with correlation between covariates. We used variance inflation factor (VIF) and multi-panel scatterplots to test for covariate collinearity. We used boxplot and Cleveland plots for outlier detection, and two-way relationships were studied through multi-panel scatterplots between the response variable (percent hatching success) and each covariate.

Restricted maximum likelihood with linear mixed models was used to investigate the effect of environmental and temporal variables on the hatching success. The response variable (percent hatching success) was logit transformed and analysed as a function of the explanatory variables considered likely to be important determinant predictors of the hatching success for sea turtles in previous studies (Wallace et al. 2004; Ditmer and

Table 1 List of explanatory variables included in mixed models to model the leatherback hatching success in the JNP. The name of each variable entered into the models, description of each one, type and levels of the categorical variables are presented

Name	Variable description	Type of variable	Levels of variables
Location			
DIST	Distance (m) to high tide line	Continuous	
ZONE	Beach zone	Categorical	Open sand/ Vegetation
SECT	Two sections separated by a rocky zone	Categorical	Bahía de las Águilas/La Cueva
Temporal			
YEAR	Breeding season year	Categorical	2007, 2008, 2009
JULIAN	Date of clutch laying	Continuous	
Reproductive			
ClutchSZ	Clutch size (number of yolked eggs)	Continuous	
YLS	Number of yolkless eggs	Continuous	
ID	Incubation duration (number of days between egg laying and the time of first hatchling emergence)	Continuous	

Stapleton 2012; see Table 1 for description). We included year as random factor in our model. It should be noted that we excluded the 2010 data from statistical analyses because some of the predictor variables were not recorded in this year due to fieldwork limitations. To identify a suitable and parsimonious approximating model, we first developed a series of alternative mixed effects models that included different combinations of the explanatory variables using stepwise process. Model selection was based on ΔAIC values lower than 2, calculated as the difference between the AIC values for each model and the model with lowest AIC, and model weights (wi) (Burnham and Anderson 2002). Model weight is a relative index for model's likelihood against any other model in the set and it was also used to calculate the relative importance of a variable by summing the weights of all the models that include that variable (Burnham and Anderson 2002). All analyses were performed using the lnme package (Pinheiro et al. 2011) in R (version 2.14.0) for the linear mixed models.

Results

In Bahía de las Águilas beach, mean ± SD hatching success of leatherback turtles clutches across years was 54.9 ± 15.5 % (n = 6), 83.5 ± 20.9 % (n = 19), 66.1 ± 24.9 % (n = 16) and 76.1 ± 20.3 % (n = 40) in 2007–2010, respectively (Fig. 2a). In La Cueva beach, mean ± SD hatching success was 81.5 ± 16.3 (n = 6) in 2007, 79.1 ± 12.0 (n = 17) in 2009 and 84.2 ± 9.6 (n = 5) in 2010 (Fig. 2a). No clutches were studied in 2008 in La Cueva beach.

We analyzed and modeled the hatching success of 64 clutches laid by leatherback turtles spanning three nesting seasons (2007, 2008 and 2009). No correlation was found between any pair of variables which were, therefore, included in the model testing the

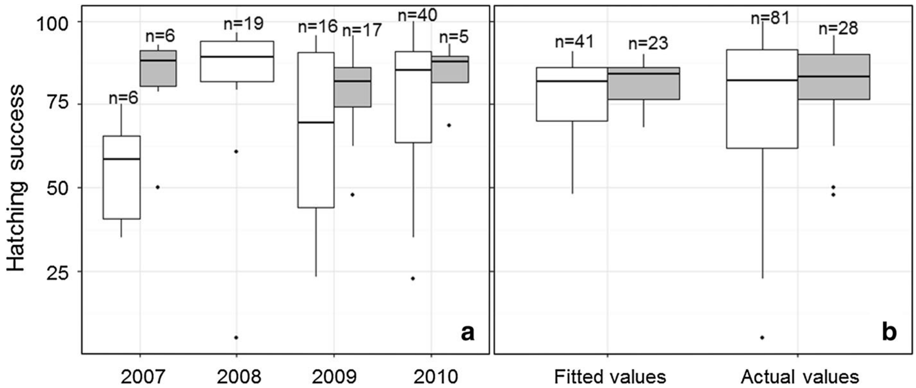

Fig. 2 **a** Hatching success of leatherback turtles in Bahía de las Águilas (*white*) and La Cueva beach (*grey*). **a** Actual data across years during the study period. No clutches were incubated in La Cueva in 2008. **b** Fitted values by locality predicted by the best model (see Table 2) compared with actual values. Numbers above bars indicate sample size

effect of seven biotic and abiotic covariates (see Table 1). Of the 25 candidate models considered, five were retained in the models selected by AIC (Table 2). The hatching success of leatherback turtles appeared to be mainly driven by the effects of characteristics of beach sector, the incubation duration and date of lay, as evidenced by the retention of these variables in the most parsimonious model (AIC = 211.32) and in all five models with ΔAIC values lower than 2 (Table 2). The relative importance of beach sector (Bahía de las Águilas and La Cueva), incubation duration and date of lay was 0.99 and the relative importance of clutch size, beach zone (open sand, or within the dune vegetation) and distance to high tide line, was 0.75, 0.35 and 0.24, respectively. Although the number of yolkless eggs was initially included in the models, this variable was not significant.

According to the best model, hatching success of clutches incubated in the beach sector of La Cueva was higher than in those incubated in Bahía de las Águilas (Table 3; Fig. 2b). In addition to beach sector, hatching success was strongly influenced by incubation duration (Table 3); longer incubation durations resulted in lower hatching success (Fig. 3a). We also found date of lay affecting hatching success, with clutches laid earlier in the nesting season having higher hatching success (Table 3; Fig. 3b). The model also showed that increasing clutch size had a negative effect on hatching success (Table 3; Fig. 3c).

Discussion

Our results show that clutches of leatherback turtles in the western beaches of the JNP presented unusually high hatching success (75.2 %) for this species in the Caribbean (~50 % see Eckert et al. 2012 for review). These beaches are of high value for the recovery of this threatened species in the Dominican Republic, taking into account the high level of egg take and the difficulties in protection in other beaches in the country (Revuelta et al. 2012). Studies on other beaches in the Caribbean region have suggested that bacterial and fungal infections (Patiño-Martínez et al. 2011), egg predation by ghost crabs, ants and other arthropoda (Maros et al. 2003; Caut et al. 2006) or non-natural predators such as feral

Table 2 List of models with better fit to the data are presented sorted according to Akaike information criterion (AIC) values. Five (out of 25) models with values of ΔAIC lower than 2 are presented. Weights of evidence in support of a particular model given the data (w) are also listed

Models	AIC	ΔAIC	*w*
HS ~ SECT + ID + JULIAN + ClutchSZ + YEAR (random factor)	211.32	0.00	0.28
HS ~ SECT + ID + JULIAN + ClutchSZ + DIST + YEAR (random factor)	211.60	0.28	0.24
HS ~ SECT + ID + JULIAN + ClutchSZ + ZONE + YEAR (random factor)	211.78	0.46	0.23
HS ~ SECT + ID + JULIAN +YEAR (random factor)	212.98	1.66	0.12
HS ~ SECT + ID + JULIAN + ZONE + YEAR (random factor)	213.12	1.79	0.12

Table 3 Estimates and standard errors (SE) from the selected model to explain the factors affecting hatching success of leatherback turtles in JNP. Model terms are described in Table 1

Variable	Estimate	SE
Intercept	10.227***	2.903
SECTOR La Cueva	0.711**	0.329
ID	−0.088**	0.036
JULIAN	−0.016**	0.006
ClutchSZ	−0.017*	0.009

Significance codes: *** P = 0–0.001; ** P = 0.01–0.05; * P = 0.05–0.1

dogs (Ordoñez et al. 2007) are important factors reducing hatching success. Additionally, the invasion of the clutch by vegetation roots, particularly from the species *Ipomoea pes-caprae*, may also have adverse effects on hatching success (Caut et al. 2010; Conrad et al. 2011). Although no quantitative data were recorded, fungal attacks (according to description in Chan and Solomon 1989) were detected in a very few clutches. The ghost crab (*Ocypode quadrata*) is present at the beaches; however, we did not observe egg predation by crabs, nor did we observe predation by ants or dogs or inundation by roots. Moreover, *I. pes-caprae* is not present in the western beaches of the JNP. Taken together the absence of these factors likely contributes to enhanced hatch rate at site. Hence, our results highlight the need to preserve the relatively pristine environments with native beach vegetation to maintain the current levels of hatchling production.

Although both sectors studied presented similar nest density, sand and vegetation, clutches at La Cueva beach had even higher hatching success than at Bahía de las Águilas, possibly due to a greater slope in the former. Apart from beach sector, the study of factors affecting hatching success revealed that incubation duration and date of lay affected hatching success. The lower hatching success found in those clutches with longer incubation durations might be associated with process of washover which could cause temperature decrease inside the clutch, thus affecting embryo development (Houghton et al. 2007; Caut et al. 2010). Furthermore, the Caribbean hurricane season starts in June when many clutches are still incubating on the beach. Hence, it is possible that the low hatching success found in clutches laid later in the season might be associated with variations in incubation temperatures due to more violent wave regimes or flooding (Santidrián Tomillo et al. 2009). Future research should explore the roles of other factors that could not be

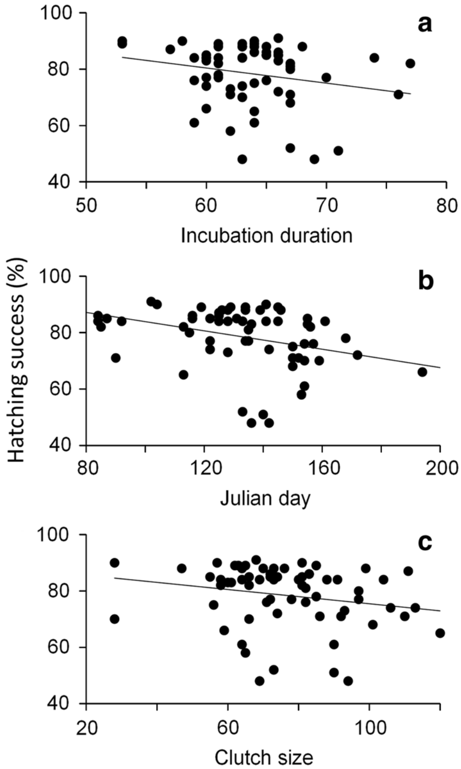

Fig. 3 Effect of **a** incubation duration, **b** Julian day (date of lay) and **c** clutch size (number of eggs incubated), on hatching success of clutches at western beaches of JNP. Shown are fitted values of the best model. Trends lines are cubic smoothing splines fitted by generalized cross-validation

recorded in this study such as nest depth, sand structure and incubation temperature, as well as individual-based reproductive variables that significantly affected hatching success in other nesting areas (Rafferty et al. 2011; Perrault et al. 2012). Since no spatial factors such as beach zone or distance to the shoreline seemed to affect hatching success, in situ clutch protection seems to be sufficient to preserve hatchling production in these beaches, avoiding the potentially negative effects of clutch relocation on hatching success (Pintus et al. 2009).

Current management strategies include surveillance of beaches and clutches by the park rangers in Bahía de las Águilas. However, the Dominican government lacks the necessary human and economic resources to effectively manage protected areas and offenses to environmental laws are frequent in these beaches, as happens in other protected areas of the country (García and Roersch 1996; Kerchner et al. 2010). Given the exceptional value of hatching success in these beaches and current and potential threats affecting leatherback nesting beaches in the country, additional effort in regulation and management of this protected area is needed. Potential actions that can be taken to improve management strategies should include increased beach surveillance by rangers during the leatherback nesting season, banning access of motorized vehicles to the beaches as well as the use of lights and campfires. Government policies should include increasing awareness to facilitate a reduction in pollution, preserve the environment, and protect the endangered species of the Park (Choi and Eckert 2009).

An added threat to the lack of enforcement is the strong pressure to bring mass tourism to this area (both in the protected and non-protected beaches) in the form of high capacity resorts. Our study is particularly relevant in relation to La Cueva beach; this sector harbors 20 % of the total clutches laid at western beaches of the Park and demonstrated the highest hatching success. However, it is less protected because it is located outside the Park limits, in the buffer zone. This means a higher level of threat as has been observed elsewhere in the country (Kerchner et al. 2010). Allowing coastal development in the buffer zone would increase detrimental effects of human activities that would impact not only this zone but also the areas inside the Park. We strongly recommend including this beach inside the limits of the park thus conferring the same level of legal protection and surveillance as Bahía de las Águilas.

Conclusions

Although Bahía de las Águilas is one of the best preserved areas in the Dominican Republic, hosting endemic species, it is threatened with increasing interest in development with plans including building of resorts and tourist facilities. Our study highlights the importance of this site and the neighbouring beach of La Cueva for leatherback turtle reproduction and the need of establishing management measures for a successful in situ conservation of this threatened species in the country. These protection measures would be also beneficial for the preservation of other species.

Acknowledgments We are very grateful to fieldwork assistants, especially to the JNP rangers for their collective conservation effort and for assistance with data collection for this project. We extend our thanks to the Dominican and international students, volunteers and local villagers who helped in different tasks of the project. The present study is included as part of a conservation project funded by: the Spanish International Cooperation Agency (AECI, projects: A/2991/05 and A/5641/06), the Spanish Ministry of Education and Sciences (CGL2006-02936-BOS), the General Foundation of the University of Valencia, and the European Union (Marie Curie grants, FP6 & 7). We specially thank the support of the Dominican NGO Grupo Jaragua and of The Nature Conservancy (TNC). The project counted on the support of the Dominican Environmental authorities (office of Protected Areas and Biodiversity of the Environmental Ministry). J. Tomás and J. A. Raga are supported by project Prometeo/2011/40 of Conselleria de Educacio (Generalitat Valenciana) and project CGL2011-30413 of the Spanish Ministry of Sciences and Innovation.

References

Bell BA, Spotila JR, Paladino FV, Reina RD (2003) Low reproductive success of leatherback turtles, *Dermochelys coriacea*, is due to high embryonic mortality. Biol Conserv 115:131–138

Buitrago J, Guada HJ, Doyle E (2008) Conservation science in developing countries: an inside perspective on the struggles in sea turtle research and conservation in Venezuela. Environ Sci Policy 11:562–578

Burnham K, Anderson D (2002) Models selection and multi-model inference. Springer, Berlin

Butchart SHM, Scharlemann PW, Evans MI, Quader S, Arico S, Arinaitwe J, Balman M, Bennun LA, Bertzky B, Besancon C, Boucher TM, Brooks TM, Burfield IJ, Burgess ND, Chan S, Clay RP, Crosby MJ, Davidson NC, De Silva N, Devenish C, Dutson GCL, Díaz Fernández DF, Fishpoo LDC, Fitzgerald C, Foster M, Heath MF, Hockings M, Hoffmann M, Knox D, Larsen FW, Lamoreux JF, Loucks C, May I, Millett J, Molloy D, Morling P, Parr M, Ricketts TH, Seddon N, Skolnik B, Stuart SN, Upgren A, Woodley S (2012) Protecting important sites for biodiversity contributes to meeting global conservation targets. PLoS One. doi:10.1371/journal.pone.0032529

Caut S, Guirlet E, Jouquet P, Girondot M (2006) Influence of nest location and yolkless eggs on the hatching success of leatherback turtle clutches in French Guiana. Can J Zool 84:815–908

Caut S, Guirlet E, Girondot M (2010) Effect of tidal overwash on the embryonic development of leatherback turtles in French Guiana. Mar Environ Res 69:254–261

CBD (2010) Secretariat of the convention on biological diversity. Global Biodiversity Outlook 3, Montreal, pp 1–94

Chan EH, Solomon SE (1989) The structure and function of the eggshell of the leatherback turtle (*Dermochelys coriacea*) from Malaysia, with notes on attached fungal forms. Anim Technol 40:91–102

Choi GY, Eckert KL (2009) Manual of best practices for safeguarding sea turtle nesting beaches. Wider Caribbean Sea Turtle Conservation Network (WIDECAST) Technical Report No. 9. Ballwin, Missouri, p 86

Conrad JR, Wyneken J, Garner JA, Garner S (2011) Experimental study of dune vegetation impact and control on leatherback sea turtle *Dermochelys coriacea* nests. Endanger Species Res 15:13–27

Ditmer MA, Stapleton SP (2012) Factors affecting hatch success of hawksbill sea turtles on Long Island, Antigua, West Indies. PLoS One. doi:10.1371/journal.pone.0038472

Eckert KL, Wallace BP, Frazier JG, Eckert SA, Pritchard PCH (2012) Synopsis of the biological data on the leatherback sea turtle (*Dermochelys coriacea*). Department of Interior, Fish and Wildlife Service, Biological Technical Publication BTP-R4015-2012, Washington

Ervin J (2003) Protected area assessments in perspective. Bioscience 53:819–822

García R, Roersch C (1996) Politica de manejo y utilización de los recursos florísticos en la República Dominicana. J Ethnopharmacol 51:147–160

Geraldes FX (2003) The coral reefs of the Dominican Republic. In: Cortés J (ed) Latin American coral reefs. Elsevier, Amsterdam, pp 303–330

Grandoit J (2005) Tourism as a development tool in the Caribbean and the environmental by-products: the stresses on small island resources and viable remedies. J Dev Soc Transf. http://www.maxwell.syr.edu/moynihan/programs/dev/journal.htlm. Accessed 19 Jan 2013

Guarderas AP, Hacker SD, Lubchenco J (2008) Current status of marine protected areas in Latin America and the Caribbean. Conserv Biol 22:1630–1640

Houghton JDR, Myers AE, Lloyd C, King RS, Isaacs C, Hays GC (2007) Protracted rainfall decreases temperature within leatherback turtle (*Dermochelys coriacea*) clutches in Grenada, West Indies: ecological implications for a species displaying temperature dependent sex determination. J Exp Mar Biol Ecol 345:71–77

Kerchner C, Honzák M, Kemkes R, Richardson A, Townsend J, Rimmer CC (2010) Designing spatially explicit incentive programs for habitat conservation: a case study of the Bicknell's thrush wintering grounds. Ecol Econ 69:2108–2115

León YM (2007) The impact of tourism on rural livelihoods in the Dominican Republic's coastal areas. J Dev Stud 43:340–359

Maros A, Louveaux A, Godfrey MH, Girondot M (2003) *Scapteriscus didactylus* (Orthoptera, Gryllotalpidae), predator of leatherback turtle eggs in French Guiana. Mar Ecol Prog Ser 249:289–296

Miller JD (1999) Determining clutch size and hatch success. In: Eckert KL, Bjorndal KA, Abreu-Grobois FA, Donnelly M (eds) Research and management techniques for the conservation of seaturtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, Washington, pp 6–8

Ordoñez C, Troëng S, Meylan A, Meylan P, Ruiz A (2007) Chiriqui Beach, Panama, the most important leatherback nesting beach in Central America. Chelonian Conserv Biol 6:122–126

Ottenwalder JA (1981) Estudio preliminar sobre el estado, distribución, y biología reproductiva de las tortugas marinas en la República Dominicana. Tesis de Licenciatura, Universidad Autónoma de Santo Domingo, Santo Domingo

Patiño-Martínez J, Marco A, Quiñones L, Godley B (2008) Globally significant nesting of the leatherback turtle (*Dermochelys coriacea*) on the Caribbean coast of Colombia and Panama. Biol Conserv 141:1982–1988

Patiño-Martínez J, Macro A, Quiñones L, Abella E, Muriel Abad R, Diéguez-Uribeondo J (2011) How do hatcheries influence embryonic development of sea turtle eggs? Experimental analysis and isolation of microorganisms in leatherback turtle eggs. J Exp Zool A 317:47–54

Perrault JR, Miller DL, Eads E, Johnson C, Merrill A, Thompson LJ, Wyneken J (2012) Maternal health status correlates with success of leatherback sea turtles (*Dermochelys coriacea*) from Florida. PLoS One. doi:10.1371/journal.pone.0031841

Pinheiro J, Bates D, DebRoy S, Sarkar D, R Development Core Team (2011) nlme: linear and nonlinear mixed effects models. R Package Version 3:1–102

Pintus KJ, Godley BJ, McGowan A, Broderick AC (2009) Impact of clutch relocation on green turtle offspring. J Wild Manag 73:1151–1157

Rafferty AR, Santidrián Tomillo P, Spotila JR, Paladino FV, Reina RD (2011) Embryonic death is linked to maternal identity in the leatherback turtle (*Dermochelys coriacea*). PLoS One. doi:10.1371/journal.pone.0021038

Revuelta O, León YM, Feliz P, Godley BJ, Raga JA, Tomás J (2012) Protected areas host important remnants of marine turtle nesting stocks in the Dominican Republic. Oryx 46:348–358

Rupp E, Incháustegui SJ, Arias Y (2005) Conservation of *Cyclura ricordii* in the southwestern Dominican Republic and a brief history of the Grupo Jaragua. Iguana 12:222–234

Santidrián Tomillo P, Suss JS, Wallace BP, Magrini KD, Blanco G, Paladino FV, Spotila JR (2009) Influence of emergence success on the annual reproductive output of leatherback turtles. Mar Biol 156:2021–2031

Wallace BP, Sotherland PR, Spotila JR, Reina RD, Franks BF, Paladino FV (2004) Biotic and abiotic factors affect the nest environment of embryonic leatherback turtles, *Dermochelys coriacea*. Physiol Biochem Zool 77:423–432

Wallace BP, DiMatteo AD, Bolten AB, Chaloupka MY, Hutchinson BJ et al (2011) Global conservation priorities for marine turtles. PLoS One. doi:10.1371/journal.pone.0024510

Wielgus J, Cooper E, Torres R, Burke L (2010) Coastal capital: Dominican Republic. Case studies on the economic value of coastal ecosystems in the Dominican Republic. Working paper, World Resources Institute, Washington

Zuur AF, Leno EN, Elphick CS (2010) A protocol for data exploration to avoid common statistical problems. Methods Ecol Evol 1:3–14