

Full title: Hematology, biochemistry, and toxicology of wild hawksbill turtles (*Eretmochelys imbricata*) nesting in mangrove estuaries in the eastern Pacific Ocean

Short title: Blood values and toxicology of EP hawksbills

Aubrey M. Tauer¹, Michael J. Liles^{2,3,4}, Sofía Chavarría^{2,3,5}, Melissa Valle^{2,3,5}, Sada Amaya⁵, Gabriela Quijada⁵, Oscar Meléndez⁵, Stanley Rodríguez⁶, Eric F. Lock⁷, Ana V. Henríquez^{2,3}, Alexander R. Gaos^{3,9,10} and Jeffrey A. Seminoff⁸.

¹Cūra Earth, Minneapolis, MN, USA;

²ProCosta, San Salvador, El Salvador

³Eastern Pacific Hawksbill Initiative, San Diego, CA, USA;

⁴Department of Biological Sciences, University of Texas at El Paso, El Paso, TX, USA

⁵Departamento de Medicina Veterinaria, Universidad de El Salvador, San Salvador, El Salvador;

⁶Centro de Investigación y Desarrollo en Salud, Universidad de El Salvador, San Salvador, El Salvador;

⁷Division of Biostatistics, School of Public Health, University of Minnesota, Minneapolis, MN, USA;

⁸National Oceanic and Atmospheric Administration – National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA, USA

⁹Biology Department, San Diego State University, San Diego, CA, USA

¹⁰Graduate Group in Ecology, University of California at Davis, Davis, CA, USA

- 25 Abstract (No limit): 251 words
- 26 Introduction through Literature Cited (No limit): 17 pages
- 27 Keywords (No limit): Conservation, health, reference ranges, sea turtle, veterinary care, blood
- 28 values
- 29 22 December 2017

Abstract

Sea turtles are a keystone species and are highly sensitive to changes in their environment, making them excellent environmental indicators. In light of environmental and climate changes, species are increasingly threatened by pollution, changes in ocean health, habitat alteration, and plastic ingestion. There may be additional health related threats and understanding these threats is key in directing future management and conservation efforts, particularly for severely reduced sea turtle populations. Hawksbill turtles (*Eretmochelys imbricata*) are critically endangered, with those in the eastern Pacific Ocean (Mexico–Peru) considered one of the most threatened sea turtle populations in the world. This study establishes baseline health parameters in hematology and blood biochemistry as well as tested for heavy metals and persistent organic pollutants in eastern Pacific hawksbills at a primary nesting colony located in a mangrove estuary. Whereas hematology and biochemistry results are consistent with healthy populations of other species of sea turtles, we identified differences in packed cell volume, heterophils and lymphocyte counts, and glucose when comparing our data to other adult hawksbill analysis (1), (2), (3). Our analysis of heavy metal contamination revealed a mean blood level of 0.245 ppm of arsenic, 0.045 ppm of lead, and 0.008 ppm of mercury. Blood levels of persistent organic pollutants were below the laboratory detection limit for all turtles. Our results suggest that differences in the feeding ecology of eastern Pacific hawksbills in mangrove estuaries may make them less likely to accumulate persistent organic pollutants and heavy metals in their blood. These baseline data on blood values in hawksbills nesting within a mangrove estuary in the eastern Pacific offer important guidance for health assessments of the species in the wild and in clinical rehabilitation facilities, and underscore the importance of preventing contamination from point and non-point sources in mangrove estuaries, which represent primary habitat to hawksbills and myriad other marine species in the eastern Pacific Ocean.

Introduction

Disease can cause declines in wildlife populations, especially those that are already threatened or vulnerable (4) (5) (6) (7). Baseline hematology and biochemistry blood parameters are useful indicators for the assessment of the health status of wild nesting sea turtle populations (8) and are especially helpful in clinical rehabilitation facilities (9). However, reference ranges for hematology and blood biochemistry are not widely available, with many reported values derived from captive animals that may not be representative of wild individuals. Additionally, data from one population of a species often are used as references for other populations, despite potential within-species variation (10) (11) (12) (13).

Hawksbill turtles (*Eretmochelys imbricata*) exemplify a species whose life history may vary widely among populations in distinct ocean basins (14) (15). In the Atlantic and Indo-Pacific, adult hawksbills primarily inhabit coral reef ecosystems (16) (17) (18) and can embark on long-distance (>2,000 km), offshore migrations between nesting and foraging areas (e.g., (19) (20)). Hawksbills in the eastern Pacific, however, often associate with mangrove ecosystems (21) (14) (22) (15) and undertake particularly short (<300 km) and neritic (<5 km) post-nesting migrations (23) (24). The marked difference in life history among hawksbills in these ocean basins could greatly influence general health parameters, which are largely unknown for adult hawksbills (3) and which have never been analyzed for individuals inhabiting mangrove estuaries. The availability of reference ranges is paramount for different populations of the same species and even subspecies, as values may even vary amongst a small population depending on diet and ecological variables (25).

Hawksbills are critically endangered globally according to the International Union for the Conservation of Nature's (IUCN) Red List (26) and the population in the eastern Pacific is among the most endangered Regional Management Units (27) for sea turtles worldwide (28).

Fewer than 700 adult female hawksbills are estimated to remain in the entire eastern Pacific Ocean (29) (15), where >80% of these individuals nest on beaches in mangrove estuaries of El Salvador and Nicaragua (30) (31) (15). These same mangrove ecosystems also provide important developmental habitat for juvenile and sub-adult hawksbills (14) (32). Known threats to this species in the region include incidental capture in coastal fisheries, human consumption of eggs, and alteration of nesting habitat (29) (31). An additional, albeit understudied potential threat to hawksbills inhabiting mangrove estuaries, is contamination by chemicals used in aquacultural and agricultural operations, including persistent pesticide residues from shrimp ponds (33) and toxic compounds discharged by surrounding rivers (34). These contaminants have been documented as negatively influencing myriad species, including estuarine fish species (35) mollusks (36) and marine turtles (37). If these contaminants are present in mangrove estuaries, reliance on such habitats could have direct impacts on health of hawksbills.

In this study, we measured blood biochemistry, hematology, and toxicological parameters in wild adult female hawksbills nesting in the Bahía de Jiquilisco mangrove estuary complex in El Salvador to establish baseline health data for one of the most important hawksbill nesting areas in the eastern Pacific. This information will establish a baseline for these parameters and aid in long-term evaluation of the health status of this severely depleted population and serve to guide future management and conservation efforts, as well as to facilitate comparisons among hawksbill populations in other oceanic basins.

99

100 **Materials and Methods**

101 *Study site*

102 Bahía de Jiquilisco (13°13'N, 88°32'W) is located in the Department of Usulután on the south-
 103 central coast of El Salvador (Fig. 1), and is a National Conservation Area, RAMSAR wetland,
 104 and UNESCO Biosphere Reserve. It contains the largest mangrove forest in El Salvador (635
 105 km²), and includes numerous islands, channels, and estuaries, with moderate development at
 106 some nesting beaches (31). Bahía de Jiquilisco has 42.1 km of hawksbill nesting habitat that
 107 includes eight discernable fine grained sand beaches with fragmented second growth coastal
 108 forest and fruit tree plantations adjacent to the high water line (15) which host ~40% of hawksbill
 109 nesting activity in the eastern Pacific (29) (31) (38).

110

111 Fig. 1. Locations of hawksbill nesting beaches with patrolled shoreline (black lines) at Bahía de
 112 Jiquilisco, El Salvador, 2013–2014.

113

114 *Beach Monitoring and Turtle Measurements*

115 Hawksbill nesting occurs primarily between April and October, with a peak in June–July. We
 116 conducted beach patrols from 1 April to 15 October 2013–2014 at Bahía de Jiquilisco, where
 117 project personnel and an extensive network of >100 trained local egg collectors monitored
 118 nesting habitat from 18:00 to 06:00 daily by foot and boat in search of female hawksbills. We
 119 identified turtles by Inconel tags (Style 681, National Brand & Tag, Newport, KY, USA) located
 120 on the second proximal scale of both front flippers and internal passive integrated transponders
 121 (PIT tags; Biomark, Boise, ID, USA) in the right front flipper; Inconel and PIT tags were either
 122 present from application during previous tagging seasons or were applied after egg laying was

completed (15). For each female hawksbill encountered, we measured curved carapace length (nuchal notch to posterior-most tip of marginal scutes; CCL) and in 2013 we performed a complete visual and physical examination, noting all epi-biota on the turtle and body condition.

Sample Collection and Analyses

We collected up to 12 ml of blood from the dorsal cervical sinus using a 10 ml syringe and 18 gauge 1.5 inch needle and immediately transferred the sample into a red-top glass serum separator tube and sodium heparin vacutainer tubes. They were not refrigerated prior to processing. Blood smears were made in our field base camp from sodium heparin-treated blood and were fixed with 99% methanol on glass slides and air dried.

We initially processed the blood in the field within 6–8 hours of blood collection. Packed cell volumes were performed using a tabletop centrifuge and whole blood in sodium heparin tubes was transferred to 1 ml cryotubes and frozen in liquid nitrogen for heavy metal analysis. The remaining blood was spun for 10 minutes at 2000 RPMs and the serum separated and frozen in cryotubes in liquid nitrogen in the field, which were subsequently stored in –20° C freezers at the University of El Salvador. Samples collected in 2013 were shipped in dry ice to the United States for hematology, serum biochemistry, heavy metal, and toxicology analyses, whereas in 2014, plasma biochemistry analyses were conducted at Centro Scan (San Salvador, El Salvador). The results were pooled for determining biochemistry reference ranges after determining that there was no statistical difference between the two sample sets.

For hematology, blood films were stained at the Minnesota Zoo with DipQuick stain (Jorgenson Laboratories, Loveland, CO, USA) for manual differential accounts of circulating white blood cells and for hemo-parasite identification. Total white blood cell counts were estimated. Samples for serum biochemistry were shipped on dry ice for processing at Marshfield

Laboratories (Marshfield, WI, USA). The biochemical panel included alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase, cholesterol, CO₂, creatine kinase (CK), glucose, lactate dehydrogenase (LDH), calcium, phosphorous, potassium, sodium, chloride, bicarbonate, total protein, anion gap and uric acid (UA). Reference intervals for biochemistry and hematology variables were computed using the package `referenceIntervals` for R (39). Parametric 95% reference intervals were computed, and the one-sample Kolmogorov-Smirnoff test (40) was used to assess the distributional assumption. For variables with a Kolmogorov-Smirnoff p-value less than 0.01, a non-parametric 95% reference interval was determined instead, with endpoints given by the 0.025 and 0.975 sample quantiles of the observed data.

Blood samples were screened at the California Animal Health and Food Safety Laboratory (San Bernadino, CA, USA) for heavy metals (arsenic [detection limit = 0.010 ppm], lead [0.050], and mercury [0.010]) and persistent organic pollutants (POP), including organochlorine insecticides (aldrin [0.010], alpha-BHC [0.010], gamma-chlordane [0.010], technical chlordane [0.050], pp-DDE [0.020], pp-DDD [0.020], pp-DDT [0.020], dicofol [0.020], op-DDE [0.020], op-DDD [0.020], op-DDT [0.020], dieldrin [0.010], endosulfan I [0.010], endosulfan II [0.010], endrin [0.010], HCB [0.010], heptachlor [0.010], heptachlor epoxide [0.010], lindane [0.010], methoxychlor [0.010]), mirex [0.010], toxaphene [0.400] and polychlorinated biphenyl (Arochlor 1221, 1232, 1242, 1248, 1254, 1260, 1262 [0.200 and 0.400]). Mean toxicity levels were determined, with 95% confidence intervals, for arsenic, lead, and mercury. If observations were missing below the limit of detection, the mean and standard deviation were inferred via maximum likelihood under the assumption that the data have a log-normal distribution that is left-censored below the limit of detection using the package `censeReg` for R (41). All data and analysis is publicly available as an annotated reproducible R code file at

<https://doi.org/10.6084/m9.figshare.5702818> and

<https://doi.org/10.6084/m9.figshare.5702779>.

Results

We encountered and examined 66 nesting hawksbills at Bahía de Jiquilisco in 2013–2014, which had a mean carapace length of 84.9 cm (SD 5.8, range = 71.0–96.6) and appeared in good general health. Physical exam findings in 2013 included two turtles that were covered in approximately 5% of epi-biotic growth; nearly all other individuals were less than 1%. Six individuals exhibited carapace damage, including missing scutes, although all appeared to have healed from the injuries. One individual had a fairly large deformity of her distal carapace, but was mobile, in good body condition, and did not have difficulty depositing eggs. Additionally, one individual had a small tumor on the right rear flipper, but logistical limitations prevented biopsy collection. Hematologic values are presented in Table 1. No hemo-parasites were observed for the 28 hawksbills evaluated in 2013. Table 2 provides the serum biochemistry reference ranges for blood collected in plain serum separator tubes in 2013 and blood plasma from sodium heparin tubes in 2014, including liver enzymes, total protein, electrolytes, and uric acid.

Table 1. Hematology reference intervals for wild hawksbill turtles (*Eretmochelys imbricata*) nesting at Bahía de Jiquilisco, El Salvador, 2013 (n = 28).

Parameter ^a	95% reference interval		KS p-value ^b
	Low	High	
PCV (%)	23.0	33.6	0.7130
WBC ($\times 10^3/\mu\text{L}$)	1228.2	10,871.8	0.0528
Heterophils (%)	43.4	93.6	0.3306
Heterophils ($\times 10^3/\mu\text{L}$)	0	8549.7	0.2120
Lymphocytes (%)	41.8	42.6	0.8327
Lymphocytes ($\times 10^3/\mu\text{L}$)	87.5	2517.7	0.8282
Monocytes (%)	0.3	11.8	0.1358
Monocytes ($\times 10^3/\mu\text{L}$)	0	748.3	0.4461
Basophils (%)	0	7.1	0.5905
Basophils ($\times 10^3/\mu\text{L}$)	0	398.4	0.8808
Eosinophils (%) ^c	0	5	<0.0001
Eosinophils ($\times 10^3/\mu\text{L}$) ^c	0	290	<0.0001

^aPCV, packed cell volume; WBC, white blood cells.

^bKS p-value, Kolmogorov-Smirnoff p-value.

^cIndicates non-parametric 95% reference interval.

Table 2. Serum chemistry reference intervals for wild hawksbill turtles (*Eretmochelys imbricata*) nesting at Bahía de Jiquilisco, El Salvador, 2013–2014 (n = 66).

Parameter ^a	n	95% reference interval		KS p-value ^b
		Low	High	
Glucose (mg/dL)	51	57.5	142.0	0.1771
AST (U/L)	51	18.3	74.3	0.8810
ALT (U/L)	33	16.3	78.1	0.8429
ALP (U/L)	51	25.7	93.6	0.4668
CK (U/L) ^c	51	121	1296.2	<0.0001
LDH (U/L) ^c	51	135.6	1645.7	0.0009
Cholesterol (mg/dL)	51	107.1	366.8	0.8260
TP (g/dL)	51	2.6	5.0	0.6850
Phosphorus (mg/dL)	18	3.4	16.1	0.6876
Calcium (mg/dL)	36	1.0	21.2	0.0379
Sodium (mmol/L)	51	140.7	169.4	0.8217
Potassium (mmol/L)	18	3.7	5.7	0.9910
Chloride (mmol/L)	51	96.9	148.5	0.1106
Bicarbonate (mmol/L)	18	9.8	33.5	0.9538
Uric Acid (mg/dL)	33	1.0	1.8	0.1846
Anion Gap (mmol/L)	18	7.6	36.8	0.2089

^aAST, aspartate aminotransferase; ALT, alanine aminotransferase; ALP, alkaline phosphatase; CK, creatine kinase; LDH, lactate dehydrogenase; TP, total protein.

^bKS p-value, Kolmogorov-Smirnoff p-value.

^cIndicates non-parametric 95% reference interval.

Levels of arsenic, lead, and mercury are presented in Table 3. Arsenic had the highest level, with a mean of 0.245 ppm (95% confidence interval = (0.10, 0.39)). Arsenic was detectable in all of the samples collected (n = 28). Lead and mercury had lower mean levels of 0.045 (95% confidence interval = (0.038, 0.056)) and 0.008 (95% confidence interval = (0.004, 0.017)) respectively. Samples from all turtles tested for POPs (n = 28) were below the detectable limits.

Table 3. Heavy metal blood values for wild hawksbill turtles (*Eretmochelys imbricata*) nesting at Bahía de Jiquilisco, El Salvador, 2013 (n = 28).

Parameter	Mean	95% CI	
		Low	High
Arsenic	0.245	0.100	0.390
Lead	0.045	0.038	0.056
Mercury	0.008	0.004	0.017

Discussion

Our results provide the first assessment of hematology, biochemistry, heavy metal, and persistent organic pollutant levels in the blood of wild hawksbills nesting in mangrove estuaries and establish baseline values for mature female hawksbills in these habitats in the eastern Pacific Ocean. The population sampled in this study was rated overall as healthy, as nesting hawksbills were in good body condition, had minimal epibiota, and generally had normal physical exam findings. While interpreting the parameters in this study, it is important to note that it is common that highly contaminated reptiles show no acute signs of health distress, thus our results should not be misinterpreted as confirming the species is healthy in the region.

Hematology and Biochemistry

The hematological and biochemistry results are generally comparable to those of other species of sea turtles sampled with healthy populations (42) (43) (44) (45) including hawksbill nesting females at open-coast beaches in Brazil (1) and for hawksbill foraging aggregations at coral reefs in the eastern Pacific (Table 4). Some differences are notable in comparing values between studies, for example glucose in the (3) study is significantly higher than that of all other studies and the Packed Cell Volume is lower in our study than in (1). Notably only eight individuals were sampled in the (3) study and the sea turtles were caught in the open water and brought on to

the beach instead of testing nesting females. The authors speculate that handling stress induced a stress hyperglycemia. This study also is the only other adult wild hawksbill study to include a white blood cell differential count, which varies from ours in numbers of heterophils and lymphocytes. The other two studies, (2) and (1) have similar values for biochemistries to our study.

One female in our study had white blood cell count and heterophil count twice as high as the lowest WBC and heterophil count sampled, so occult illness in one or more individuals of our studied population may be possible (46). Biochemistry reference ranges were established (2) for juvenile hawksbills occupying a coral reef ecosystem off the Pacific coast of Colombia, with calcium, total protein, phosphorus, glucose values similar to our data, but with much wider ranges of LDH, AST, and cholesterol. Some differences were noted between several hematological and biochemistry values when compared to published data from juvenile hawksbills undergoing rehabilitation in the United Arab Emirates (47). For example, juvenile hawksbills had lower mean PCVs, lower total white blood cell counts, and higher AST, CK, and uric acid levels. Additionally, mean calcium, phosphorus, and total protein levels were lower in the rehabilitated animals when compared to our study sample. These differences may be due, at least in part, to the impaired health of animals in rehabilitation, as well as possible geographic variation in environmental variables or in the life-history characteristics of hawksbills in distinct oceanic regions. Variation in biochemistry ranges may reflect differences in physiological requirements between life stages (i.e. juvenile vs. adults) and/or behavior/habitats (nesting in mangrove estuaries vs foraging at coral reef ecosystems) of each studied hawksbill population (15).

296 Table 4. Available blood values for hawksbill turtles.

Parameter ^a	Wrobel Goldberg et al. 2013			Tobón-López & Amorcho Llanos 2014			Muñoz-Pérez et al. 2017			Tauer et al. this study		
	Mean	SD	n ^b	Mean	SD	n ^c	Mean	SD	n ^d	Mean	SD	n ^e
<i>Hematology</i>												
PCV (%)	39.4	2.9	41	–	–	–	–	–	–	28.34	7.71	28
RBC ($\times 10^{12}/L$)	–	–	–	–	–	–	0.35	0.09	8	–	–	–
WBC ($\times 10^9/L$)	–	–	–	–	–	–	5.31	3.86	8	–	–	–
Heterophils (%)	–	–	–	–	–	–	32.3	6.9	8	65.5	12.81	28
Lymphocytes (%)	–	–	–	–	–	–	45.9	6.1	8	22.21	10.4	28
Monocytes (%)	–	–	–	–	–	–	3.6	1.9	8	6.04	2.92	28
Basophils (%)	–	–	–	–	–	–	0.1	0.2	8	2.82	2.20	28
Eosinophils (%)	–	–	–	–	–	–	18.5	4.5	8	0.36	0.99	28
<i>Biochemistry</i>												
Glucose (mg/dL)	98.6	14.6	41	103.5	16.6	11	1567.6	180.2	7	99.71	21.56	51
AST (U/L)	55.4	7.1	41	132.6	111.2	11	196	54	8	46.33	14.29	51
ALT (U/L)	6.6	2.4	41	–	–	–	38	15	8	47.18	15.75	33
ALP (U/L)	15.9	3.7	41	–	–	–	53	26	8	56.63	17.33	51
LDH (U/L)	–	–	–	136.5	78.9	11	–	–	–	394.41	288.12	51
Cholesterol (mg/dL)	287	42	41	84.5	30.9	11	–	–	–	236.92	66.24	51
TP (g/dL)	5.45	0.63	41	2.5	0.7	11	4.8	0.7	8	3.79	0.62	51
Phosphorus (mg/dL)	11.3	1.4	41	6.7	2	11	–	–	–	9.76	3.23	18
Calcium (mg/dL)	11.6	1.5	41	7.8	1.8	11	–	–	–	11.09	5.14	36
Sodium (mmol/L)	139.6	3.5	41	–	–	–	157	2	7	155.04	7.33	51
Potassium (mmol/L)	5.09	0.76	41	–	–	–	4.2	0.4	7	4.68	0.51	18
Chloride (mmol/L)	–	–	–	–	–	–	–	–	–	122.71	13.14	51
Biocarbonate (mmol/L)	–	–	–	–	–	–	–	–	–	21.61	6.05	18
Uric Acid (mg/dL)	0.95	0.17	41	3.7	2.7	11	–	–	–	1.39	0.20	33
Anion Gap (mmol/L)	–	–	–	–	–	–	–	–	–	22.22	7.45	18

297 ^aPCV, packed cell volume; RBC, red blood cells; WBC, white blood cells; AST, aspartate aminotransferase; ALT, alanine aminotransferase; ALP, alkaline
298 phosphatase; CK, creatine kinase; LDH, lactate dehydrogenase; TP, total protein.

299 ^bHawksbills nesting on open-coast beaches in Brazil, Atlantic Ocean.

300 ^cHawksbills foraging at coral reefs in Colombia, Pacific Ocean.

301 ^dHawksbills foraging at coral reefs in Ecuador, Pacific Ocean.

302 ^eHawksbills nesting on beaches within mangrove estuaries in El Salvador, Pacific Ocean.

Heavy Metals

Heavy metal values appear variable amongst species and subpopulations in loggerhead (*Caretta caretta*), kemp's ridley (*Lepidochelys kempii*), and green (*Chelonia mydas*) turtles (48) (49) (50), and are likely related to environmental effects, diet, age, and geography. While hawksbills are omnivorous, their diet worldwide is primarily composed of sponges (51), which are of low trophic level and may explain lower levels of contaminants than sea turtle species that eat items higher up on the food chain, such as olive ridley (*Lepidochelys olivacea*) and kemp's ridley turtles (48). Adult hawksbills have been documented having relatively low concentrations of the heavy metals in their blood, although maternal transfer of heavy metals from adult hawksbills to their eggs is known to occur (43).

Higher levels of arsenic were found in adult hawksbill tissues in Japan, particularly in muscle, than compared to adult green turtles (52). Additionally, arsenic levels of marine sponges were found to range from 0.8–157 mgm/gram of dry weight, suggesting that sponges may be a significant source of arsenic in adult hawksbills. It is unclear the role that sponges may play in accumulation of other heavy metals or persistent organic pollutants, such as the low levels of lead and mercury found in our study population.. Importantly, hawksbills in our study area utilize mangrove estuaries and are believed to feed predominantly on mangrove seeds and roots (M. Liles, pers. obs.), indicating that they may feed at an even lower trophic level than populations of hawksbills in other regions. The tendency to feed at low trophic levels may enable eastern Pacific hawksbills to avoid higher levels of blood pollutants seen in conspecifics in other habitats, as well as other sea turtle species.

Persistent Organic Pollutants

Organic and inorganic pollutants have been more frequently studied in loggerheads than other sea turtle species (53) (54) (55). Studies on loggerheads have found detectable POP and PCB results in which several of the individual contaminants had correlations with changes in clinical parameters such as packed cell volume (56). Further studies are needed on all sea turtle species to determine the individual and population level effects on health and reproductive outcomes in animals exposed to inorganic and organic pollutants.

The trophic level of food items consumed by sea turtle species at different life stages may impact levels of POP and PCBs. For instance, green turtles consume marine invertebrates as juveniles before transitioning to primarily algae and sea grass as adults, whereas adult leatherback and hawksbills forage on jellyfish and primarily marine sponges, respectively (57). For hawksbills and leatherbacks, this may mean they tend to accumulate more pollutants. More recently, however, leatherback turtles (*Dermochelys coriacea*) in Gabon with evaluated levels of POP and PCB in the blood of nesting and all turtles had levels below the detectable limit (42), a recent study (58) off the west coast of Senegal in the Cape Verde Islands comparing POP and PCB levels in juvenile green and hawksbill turtles found detectable levels in both species, although green turtles had both higher levels and a greater prevalence of contamination. Trophic levels might not reflect higher levels of POP in adult green and hawksbill turtles and viable turtle eggs (59).

Conclusions

Our study provides baseline health data for hawksbills nesting at a primary rookery located in a mangrove estuary in the eastern Pacific Ocean, which can provide a starting point for long-term monitoring of health status of hawksbills in the region and offer diagnostic indications for

treatment of individuals in clinical rehabilitation. Additional studies between healthy juvenile and adult hawksbills in both mangrove estuaries and other habitats should be conducted to delineate size or age related differences in biochemistry and hematologic values in this species, as apparent health status may not reflect contaminant loads. We suggest that future research determine contaminant loads of marine sponges and mangrove vegetation in the Bahía de Jiquilisco and the potential role they play in accumulation of toxins in the environment. It is possible ecosystem processes are occurring that prevent uptake of toxins in the environment to the sea turtles themselves, or through their diet, which, contrary to most hawksbill populations, includes substantially more vegetation (60). Further studies at Bahia de Jiquilisco utilizing skin, muscle, carapace, fat and liver may provide different results than those obtained in this study.

Acknowledgements

We thank local egg collectors at Bahía de Jiquilisco for their collaboration—this study would have been impossible without their knowledge and participation. We acknowledge N. Sanchez, O. Rivera, F. López, G. Serrano Liles, D. Melero, E. LaCasella, F. Rivas, M. Hidalgo, W. J. Nichols, J. Urteaga, E. Ramírez, and C. Dueñas for assistance. We are grateful to the following institutions for permits: Ministry of Environment and Natural Resources in El Salvador (sample collection: MARN-AIMA-DGBPN-GVS-054-2013; MARN-DEVS-GVS-26-2014), Ministry of Agriculture and Ranching in El Salvador (sample export: CITES 09105), and Southwest Fisheries Science Center (NMFS-NOAA) in United States (sample import: CITES 13US844694/9). Research ethics were evaluated by Cūra Earth’s scientific advisory group. We thank The Rufford Foundation for funding.

Literature Cited

1. Goldberg DW, Leitão SAT, Godfrey MH, Lopez GG, Santos AJBB, Neves FA, et al. Ghrelin and leptin modulate the feeding behaviour of the hawksbill turtle *Eretmochelys imbricata* during nesting season. *Conserv Physiol* [Internet]. Saunders Elsevier, St Louis; 2013 Jul 2 [cited 2017 Jun 2];1(1):1–13. Available from: <https://academic.oup.com/conphys/article-lookup/doi/10.1093/conphys/cot016>
2. Tobón-López A, Amorcho Llanos DF. Population Study of the Hawksbill Turtle *Eretmochelys imbricata* (Cheloniidae) in the Southern Pacific region of Colombia. *Acta Biológica Colomb* [Internet]. Universidad Nacional de Colombia; 2014 Jun 20 [cited 2017 Jun 2];19(3):447. Available from: <http://www.revistas.unal.edu.co/index.php/actabiol/article/view/42434>
3. Muñoz-pérez JP, Lewbart GA, Hirschfeld M, Alarcón-ruales D, Denkinger J, Guillermo J, et al. Blood gases , biochemistry and haematology of Galápagos hawksbill turtles (*Eretmochelys imbricata*). 2017;5:1–9.
4. Laurenson K, Sillero-Zubiri C, Thompson H, Shiferaw F, Thirgood S, Malcolm J. Disease as a threat to endangered species: Ethiopian wolves, domestic dogs and canine pathogens. *Anim Conserv* [Internet]. Blackwell Publishing Ltd; 1998 Nov [cited 2016 Jul 5];1(4):273–80. Available from: <http://doi.wiley.com/10.1111/j.1469-1795.1998.tb00038.x>
5. Daszak P, Cunningham AA, Hyatt AD. Infectious disease and amphibian population declines [Internet]. Vol. 9, Diversity and Distributions. Blackwell Science Ltd; 2003 [cited 2017 Dec 14]. p. 141–50. Available from: <http://doi.wiley.com/10.1046/j.1472-4642.2003.00016.x>
6. Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, et al. Status

and trends of amphibian declines and extinctions worldwide. *Science* (80-) [Internet]. American Association for the Advancement of Science; 2004 Dec 3 [cited 2016 Jul 5];306(October):1783–6. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/15486254>

7. Frick WF, Pollock JF, Hicks AC, Langwig KE, Reynolds DS, Turner GG, et al. An emerging disease causes regional population collapse of a common North American bat species. *Science* [Internet]. American Association for the Advancement of Science; 2010 Aug 6 [cited 2016 Jul 5];329(5992):679–82. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/20689016>

8. Aguirre AA, Balazs G. Blood biochemistry values of green turtles, *Chelonia mydas*, with and without fibropapillomatosis. *Comp Haematology Int*. 2000;10:132–7.

9. Norton TM, Walsh MT. Sea turtle rehabilitation [Internet]. *Fowler’s zoo and wild animal medicine, Volume 7: current therapy*. 2012 [cited 2017 Dec 14]. 239-246 p. Available from: https://scholar.google.com.ni/scholar?hl=en&as_sdt=0%2C5&q=norton+sea+turtle+rehabilitation&oq=norton+sea+turtle+rehabilitation

10. Pullin AS, Knight TM, Stone DA, Charman K. Do conservation managers use scientific evidence to support their decision-making? *Biol Conserv* [Internet]. 2004;119(2):245–52. Available from: <http://www.sciencedirect.com/science/article/pii/S000632070300449X>

11. Sutherland WJ, Pullin AS, Dolman PM, Knight TM. The need for evidence-based conservation. *Trends Ecol Evol* [Internet]. 2004;19(6):305–8. Available from: <http://www.sciencedirect.com/science/article/pii/S0169534704000734>

12. Pullin AS, Knight TM. Doing more good than harm – Building an evidence-base for conservation and environmental management. *Biol Conserv* [Internet]. 2009;142(5):931–4. Available from: <http://www.sciencedirect.com/science/article/pii/S0006320709000421>

13. Katselidis KA, Schofield G, Stamou G, Dimopoulos P, Pantis JD. Evidence-based management to regulate the impact of tourism at a key marine turtle rookery on Zakynthos Island, Greece. *Oryx* [Internet]. 2013/07/24. Cambridge University Press; 2013;47(4):584–94. Available from: <https://www.cambridge.org/core/article/evidencebased-management-to-regulate-the-impact-of-tourism-at-a-key-marine-turtle-rookery-on-zakynthos-island-greece/C5A75DB414CDD3F1B372750721041496>
14. Gaos AR, Lewison RL, Yañez IL, Wallace BP, Liles MJ, Nichols WJ, et al. Shifting the life-history paradigm: discovery of novel habitat use by hawksbill turtles. *Biol Lett* [Internet]. The Royal Society; 2012 Feb 23 [cited 2017 Nov 17];8(1):54–6. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/21880620>
15. Liles MJ, Peterson MJ, Seminoff JA, Altamirano E, Henríquez A V, Gaos AR, et al. One size does not fit all: Importance of adjusting conservation practices for endangered hawksbill turtles to address local nesting habitat needs in the eastern Pacific Ocean. *Biol Conserv* [Internet]. 2015;184(Supplement C):405–13. Available from: <http://www.sciencedirect.com/science/article/pii/S0006320715000877>
16. MEYLAN A. Spongivory in Hawksbill Turtles: A Diet of Glass. *Science* (80-) [Internet]. American Association for the Advancement of Science; 1988 [cited 2017 Nov 17];239(4838):393–5. Available from: <http://www.jstor.org/stable/pdf/1700236.pdf>
17. León Y, Bjørndal K. Selective feeding in the hawksbill turtle, an important predator in coral reef ecosystems. *Mar Ecol Prog Ser* [Internet]. 2002 [cited 2013 Feb 28]; Available from: <http://www.vliz.be/imisdocs/publications/75611.pdf>
18. Bell I. Algivory in hawksbill turtles: *Eretmochelys imbricata* food selection within a foraging area on the Northern Great Barrier Reef. *Mar Ecol* [Internet]. Blackwell Publishing Ltd; 2013 Mar 1 [cited 2017 Dec 21];34(1):43–55. Available from:

<http://doi.wiley.com/10.1111/j.1439-0485.2012.00522.x>

19. Miller JD, Dobbs KA, Limpus CJ, Mattocks N, Landry AM. Long-distance migrations by the hawksbill turtle, *Eretmochelys imbricata*, from north-eastern Australia. *Wildl Res.* 1998;25(1):89–95.
20. Van Dam R, Diez C, Balazs G, Colón Colón L, McMillan W, Schroeder B. Sex-specific migration patterns of hawksbill turtles breeding at Mona Island, Puerto Rico. *Endanger Species Res* [Internet]. 2008 Jan 18 [cited 2017 Dec 21];4(1–2):85–94. Available from: <http://www.int-res.com/abstracts/esr/v4/n1-2/p85-94/>
21. Liles M, Jandres M, López W, Mariona G, Hasbún C, Seminoff J. Hawksbill turtles *Eretmochelys imbricata* in El Salvador: nesting distribution and mortality at the largest remaining nesting aggregation in the eastern Pacific Ocean. *Endanger Species Res* [Internet]. 2011 Apr;14(1):23–30. Available from: <http://www.int-res.com/abstracts/esr/v14/n1/p23-30/>
22. Chacón-Chaverri D, Martínez-Cascante DA, Rojas D, Fonseca LG. Golfo Dulce, Costa Rica, an important foraging ground for the Pacific hawksbill turtle (*Eretmochelys imbricata*). *Rev Biol Trop* [Internet]. 2016 Feb 3 [cited 2017 Dec 21];63(1):351–62. Available from: <https://revistas.ucr.ac.cr/index.php/rbt/article/view/23114>
23. Gaos AR, Lewison RR, Wallace BP, Yañez IL, Liles MJ, Baquero A, et al. Dive behaviour of adult hawksbills (*Eretmochelys imbricata*, Linnaeus 1766) in the eastern Pacific Ocean highlights shallow depth use by the species. *J Exp Mar Bio Ecol* [Internet]. 2012;432–433(Supplement C):171–8. Available from: <http://www.sciencedirect.com/science/article/pii/S0022098112002699>
24. Gaos A, Lewison R, Wallace B, Yañez I, Liles M, Nichols W, et al. Spatial ecology of critically endangered hawksbill turtles *Eretmochelys imbricata*: implications for

- management and conservation. Mar Ecol Prog Ser [Internet]. 2012 Mar 29 [cited 2017 Dec 21];450:181–94. Available from: <http://www.int-res.com/abstracts/meps/v450/p181-194/>
25. Seal US, Nelson ME, Mech LD, Hoskinson RL. Metabolic Indicators of Habitat Differences in Four Minnesota Deer Populations. J Wildl Manage [Internet]. WileyWildlife Society; 1978 Oct [cited 2017 Dec 21];42(4):746. Available from: <http://www.jstor.org/stable/3800765?origin=crossref>
26. Turtle H, Mortimer AJ a, Donnelly M. Hawksbill Turtle. Uicn. 2008;
27. Wallace BP, DiMatteo AD, Hurley BJ, Finkbeiner EM, Bolten AB, Chaloupka MY, et al. Regional Management Units for Marine Turtles: A Novel Framework for Prioritizing Conservation and Research across Multiple Scales. Bograd SJ, editor. PLoS One [Internet]. 2010 Dec 17 [cited 2017 Dec 21];5(12):e15465. Available from: <http://dx.plos.org/10.1371/journal.pone.0015465>
28. Wallace BP, DiMatteo AD, Bolten AB, Chaloupka MY, Hutchinson BJ, Abreu-Grobois FA, et al. Global Conservation Priorities for Marine Turtles. Bograd SJ, editor. PLoS One [Internet]. Public Library of Science; 2011 Sep 28 [cited 2017 Dec 21];6(9):e24510. Available from: <http://dx.plos.org/10.1371/journal.pone.0024510>
29. Gaos AR, Abreu-Grobois F a., Alfaro-Shigueto J, Amorocho D, Arauz R, Baquero a., et al. Signs of hope in the eastern Pacific: international collaboration reveals encouraging status for a severely depleted population of hawksbill turtles *Eretmochelys imbricata*. Oryx [Internet]. 2010 Aug;44(4):595–601. Available from: http://www.journals.cambridge.org/abstract_S0030605310000773
30. Altamirano E, Torres P, Manzanares L, Maradiaga E, Seminoff JA, Urteaga J, et al. Surpassing the wildest of expectations: a newly discovered hawksbill (*Eretmochelys imbricata*) nesting rookery in the Estero Padre Ramos Natural Reserve, Nicaragua,

provides new hope for recovery of the species in the eastern Pacific. In: Proceedings of the Thirty-first Annual Symposium on Sea Turtle Biology and Conservation eds TT Jones, BP Wallace, San Diego, CA, USA. 2011.

31. Liles M, Jandres M, López W, Mariona G, Hasbún C, Seminoff J. Hawksbill turtles *Eretmochelys imbricata* in El Salvador: nesting distribution and mortality at the largest remaining nesting aggregation in the eastern Pacific Ocean. *Endanger Species Res* [Internet]. 2011 Apr 7 [cited 2013 Feb 28];14(1):23–30. Available from: <http://www.int-res.com/abstracts/esr/v14/n1/p23-30/>

32. Gaos AR, Lewison RL, Liles MJ, Gadea V, Altamirano E, Henríquez A V., et al. Hawksbill turtle terra incognita: conservation genetics of eastern Pacific rookeries. *Ecol Evol* [Internet]. 2016 Feb 1 [cited 2017 Dec 21];6(4):1251–64. Available from: <http://doi.wiley.com/10.1002/ece3.1897>

33. Amaya E, Roa A, Camacho J, Meneses S. Valoración de factores de riesgo asociados a los hábitos de manejo y exposición a organofosforados y carbamatos en habitantes y trabajadores de la vereda de Bateas del municipio de Tibacuy . *Publicación Científica en ciencias Biomédicas* [Internet]. 2008;6(10):147–55. Available from: http://www.unicolmayor.edu.co/invest_nova/NOVA/NOVA10_ARTORIG4_BATEAS.pdf

34. Carvalho FP, Montenegro-Guillen S, Villeneuve JP, Cattini C, Bartocci J, Lacayo M, et al. Chlorinated hydrocarbons in coastal lagoons of the pacific coast of Nicaragua. *Arch Environ Contam Toxicol*. 1999;36(2):132–9.

35. Stentiford G., Longshaw M, Lyons B., Jones G, Green M, Feist S. Histopathological biomarkers in estuarine fish species for the assessment of biological effects of contaminants. *Mar Environ Res* [Internet]. Elsevier; 2003 Mar 1 [cited 2017 Dec

- 516 21];55(2):137–59. Available from:
- 517 <http://www.sciencedirect.com/science/article/pii/S014111360200212X>
- 518 36. Tsangaris C, Cotou E, Papathanassiou E, Nicolaidou A. Assessment of contaminant
519 impacts in a semi-enclosed estuary (Amvrakikos Gulf, NW Greece): Bioenergetics and
520 biochemical biomarkers in mussels. *Environ Monit Assess* [Internet]. Springer
521 Netherlands; 2010 Feb 4 [cited 2017 Nov 17];161(1–4):259–69. Available from:
522 <http://link.springer.com/10.1007/s10661-008-0743-2>
- 523 37. Komoroske LM, Lewison RL, Seminoff JA, Deheyn DD, Dutton PH. Pollutants and the
524 health of green sea turtles resident to an urbanized estuary in San Diego, CA.
525 *Chemosphere* [Internet]. Pergamon; 2011 Jul 1 [cited 2017 Dec 21];84(5):544–52.
526 Available from: <http://www.sciencedirect.com/science/article/pii/S0045653511004140>
- 527 38. Gaos AR, Liles MJ, Gadea V, Pena A, Vallejo F, Miranda C, et al. Living on the Edge:
528 Hawksbill turtle nesting and conservation along the Eastern Pacific Rim. *Lat Am J Aquat*
529 *Res* [Internet]. Pontificia Universidad Católica de Valparaíso. Facultad de Recursos
530 Naturales. Escuela de Ciencias del Mar; 2017 Jul 10 [cited 2017 Dec 22];45(3):572–84.
531 Available from: http://www.lajar.cl/pdf/imar/v45n3/Artículo_45_3_7.pdf
- 532 39. Finnegan D. CRAN - Package referenceIntervals [Internet]. 2014 [cited 2017 Dec 22].
533 Available from: <https://cran.r-project.org/web/packages/referenceIntervals/index.html>
- 534 40. Massey FJ. The Kolmogorov-Smirnov Test for Goodness of Fit. *J Am Stat Assoc*
535 [Internet]. 1951 Mar [cited 2017 Dec 22];46(253):68–78. Available from:
536 <http://www.tandfonline.com/doi/abs/10.1080/01621459.1951.10500769>
- 537 41. Henningsen A. CRAN - Package censReg [Internet]. [cited 2017 Dec 22]. Available from:
538 <https://cran.r-project.org/web/packages/censReg/index.html>
- 539 42. Deem SL, Dierenfeld ES, Sounguet GP, Alleman AR, Cray C, Poppenga RH, et al. Blood

values in free-ranging nesting leatherback sea turtles (*Dermochelys coriacea*) on the coast of the Republic of Gabon. *J zoo Wildl Med Off Publ Am Assoc Zoo Vet* [Internet]. American Association of Zoo Veterinarians; 2006;37(4):464–71. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/17315430>

43. Ehsanpour M, Afkhami M, Khoshnood R, Reich KJ. Determination and Maternal Transfer of Heavy Metals (Cd, Cu, Zn, Pb and Hg) in the Hawksbill Sea Turtle (*Eretmochelys imbricata*) from a Nesting Colony of Qeshm Island, Iran. *Bull Environ Contam Toxicol* [Internet]. 2014 Jun 6;92(6):667–73. Available from: <http://link.springer.com/10.1007/s00128-014-1244-3>

44. Fazio E, Liotta A, Medica P, Giaccoppo E, Ferlazzo A. Effects of different health status on blood haematochemical values of loggerhead sea turtles (*Caretta caretta*). *Comp Clin Path* [Internet]. 2010 Feb;21(1):105–9. Available from: <http://link.springer.com/10.1007/s00580-010-1070-x>

45. Fazio E, Liotta A, Medica P, Bruschetta G, Ferlazzo A. Serum and plasma biochemical values of health loggerhead sea turtles (*Caretta caretta*). *Comp Clin Path* [Internet]. 2012 Oct 22;21(5):905–9. Available from: <http://link.springer.com/10.1007/s00580-011-1197-4>

46. Sykes IV J, Klaphake E. Reptile hematology. *Vet Clin North Am Exot Anim Pract* [Internet]. Elsevier; 2008 Sep 1 [cited 2017 Nov 17];11(3):491–500. Available from: <http://www.sciencedirect.com/science/article/pii/S1094919408000236>

47. Hampel¹ M, Robinson D, Baverstock W, Hyland K. Haematology and biochemistry blood parameters of juvenile hawksbill turtles (*Eretmochelys imbricata*). *Wildl Middle East News* [Internet]. 2009;4(3):8237. Available from: http://wmenews.com/~wmenews0/newsletters/File/Volume-4/Issue-3/WME_News_V4I3_C_E07.pdf

48. Cortés-Gómez AA, Fuentes-Mascorro G, Romero D. Metals and metalloids in whole blood and tissues of Olive Ridley turtles (*Lepidochelys olivacea*) from La Escobilla Beach (Oaxaca, Mexico). *Mar Pollut Bull* [Internet]. 2014 Dec;89(1–2):367–75. Available from: <http://linkinghub.elsevier.com/retrieve/pii/S0025326X14006444>
49. Gardner SC, Fitzgerald SL, Vargas BA, Rodriguez LM. Heavy metal accumulation in four species of sea turtles from the Baja California Peninsula, Mexico. *Biometals*. 2006;19(1):91–9.
50. Sakai H, Saeki K, Ichihashi H, Suganuma H, Tanabe S, Tatsukawa R. Species-specific distribution of heavy metals in tissues and organs of loggerhead turtle (*Caretta caretta*) and green turtle (*Chelonia mydas*) from Japanese coastal waters. *Mar Pollut Bull* [Internet]. 2000;40(8):701–9. Available from: http://www.sciencedirect.com/science/article/B6V6N-40X8F9D-8/2/6de2165bb3335f3d5e67139910fccf33%5Cnhttp://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V6N-40X8F9D-8&_user=554534&_coverDate=08/31/2000&_alid=1131379999&_rdoc=47&_fmt=high&_orig=search&_
51. Meylan A. Spongivory in Hawksbill Turtles: A Diet of Glass. *Science* (80-) [Internet]. 1988 [cited 2017 May 25];239(4838):393–5. Available from: <http://go.galegroup.com/ps/i.do?p=AONE&sw=w&issn=00368075&v=2.1&it=r&id=GAL E%7CA6331423&sid=googleScholar&linkaccess=fulltext>
52. Agusa T, Takagi K, Kubota R, Anan Y, Iwata H, Tanabe S. Specific accumulation of arsenic compounds in green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) from Ishigaki Island, Japan. *Environ Pollut*. 2008;153(1):127–36.
53. Lazar B, Maslov L, Romanić SH, Gračan R, Krauthacker B, Holcer D, et al. Accumulation

- of organochlorine contaminants in loggerhead sea turtles, *Caretta caretta*, from the eastern Adriatic Sea. Chemosphere [Internet]. Pergamon; 2011 Jan 1 [cited 2017 Dec 22];82(1):121–9. Available from: <http://www.sciencedirect.com/science/article/pii/S004565351001012X>
54. Keller JM, Ngai L, McNeill JB, Wood LD, Stewart KR, O’Connell SG, et al. Perfluoroalkyl contaminants in plasma of five sea turtle species: Comparisons in concentration and potential health risks. Environ Toxicol Chem. 2012;
55. Monagas P, Orós J, Araña J, González-Díaz OM. Organochlorine pesticide levels in loggerhead turtles (*Caretta caretta*) stranded in the Canary Islands, Spain. Mar Pollut Bull [Internet]. 2008 Nov [cited 2017 Dec 22];56(11):1949–52. Available from: <http://linkinghub.elsevier.com/retrieve/pii/S0025326X08004232>
56. Camacho M, Luzardo OP, Boada LD, López Jurado LF, Medina M, Zumbado M, et al. Potential adverse health effects of persistent organic pollutants on sea turtles: Evidences from a cross-sectional study on Cape Verde loggerhead sea turtles. Sci Total Environ [Internet]. 2013 Aug;458–460:283–9. Available from: <http://linkinghub.elsevier.com/retrieve/pii/S0048969713004658>
57. Bjorndal K, Lutz P, Musick J. Foraging ecology and nutrition of sea turtles. Biol sea turtles [Internet]. 1997 [cited 2017 May 25]; Available from: <https://books.google.com/books?hl=en&lr=&id=fhm2yGTBiN8C&oi=fnd&pg=PA199&dq=mortimer+hawksbill+sea+turtles&ots=Xl8C3INNER&sig=FXMoQLYqf3Eow0kVxK35W2bC7OU>
58. Camacho M, Boada LD, Orós J, López P, Zumbado M, Almeida-González M, et al. Monitoring organic and inorganic pollutants in juvenile live sea turtles: Results from a study of *Chelonia mydas* and *Eretmochelys imbricata* in Cape Verde. Sci Total Environ

[Internet]. Elsevier; 2014 May 15 [cited 2017 Dec 22];481:303–10. Available from:
<http://www.sciencedirect.com/science/article/pii/S0048969714002253>

59. García-Besné G, Valdespino C, Rendón-von Osten J. Comparison of organochlorine pesticides and PCB residues among hawksbill (*Eretmochelys imbricata*) and green (*Chelonia mydas*) turtles in the Yucatan Peninsula and their maternal transfer. *Mar Pollut Bull.* 2015;91(1):139–48.

60. Gaos AR, Lewison RL, Yañez IL, Wallace BP, Liles MJ, Nichols WJ, et al. Shifting the life-history paradigm: discovery of novel habitat use by hawksbill turtles. *Biol Lett* [Internet]. 2011 Aug 31; Available from:
<http://rsbl.royalsocietypublishing.org/content/early/2011/08/23/rsbl.2011.0603.abstract>