Roatán Marine Park, Roatán, Honduras

IMPACTS OF RECREATIONAL DIVING ON HAWKSBILL SEA TURTLES (*ERETMOCHELYS IMBRICATA*) IN THE ROATÁN MARINE PARK, HONDURAS

Summer 2014 RESEARCH REPORT

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SUMMER 2014 RESEARCH REPORT

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PREFACE

This report represents the ongoing work of the Protective Turtle Ecology Center for Training, Outreach, and Research, Inc. (ProTECTOR Inc.) in Honduras during the 2014 season and is provided in partial fulfillment of research agreements with the Roatán Marine Park.

ACKNOWLEDGMENTS

ProTECTOR Inc. thanks the Department of Earth and Biological Sciences (Loma Linda University) for their generous financial assistance. We thank the Roatán Marine Park for their collaboration in conducting this study and for providing logistical support. For thoughtful reviews of the research we thank the Marine Research Group (LLU) and Elizabeth Dossett. We also thank Khaled Bahjri and Briana Wells for help with statistical analysis, Ed Santos and Lance PompevMeerddervoort for ArcGis™ support, and Lidia Salinas for help with logistics and in securing permits in Honduras. We thank DIGEPESCA and SAG for research permits, Jimmy Miller for transportation, and Splash Inn, Coconut Tree Divers, and West End Divers for providing us with dives. We also thank research assistants Marsha Wright and Linda Baeza, and the many divemasters, boat captains, and volunteers who helped us with data collection. These studies were conducted under approval from DIGEPESCA (SAG-No-36-2012) and the Loma Linda University Institutional Animal Care and Use Committee (IACUC) (Protocol #89029), and are in compliance with United States and Honduran law.

April 11, 2016

Cover image: Scuba diver with juvenile *Eretmochelys imbricata* in the Roatán Marine Park. Photo: © S.G. Dunbar, 2014

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INTRODUCTION AND BACKGROUND

A comprehensive background on the work of ProTECTOR Inc. on the hawksbill sea turtle (*Eretmochelys imbricata*) in Honduras has been provided in reports to DIGEPESCA, SAG, and the USFWS (Dunbar 2006, Dunbar and Berube 2008, Dunbar and Salinas 2009, Dunbar et al. 2013, Dunbar and Salinas 2013). Each report provides details regarding methods carried out under SAG permits **#DGPA/005/2006; DGPA/245/2006; DGPA/5428/2007, DGPA/707/2009, SAG/251/2010**, and **SAG/036/2012**, and provides results obtained up to August 2013.

We provide the following report on the activities of ProTECTOR Inc. between June and August, 2014, in the Roatán Marine Park (RMP), Honduras. The primary goal of these studies was to quantify the impacts of recreational diving on juvenile hawksbill sea turtles in the RMP. We conducted in-water observations of juvenile hawksbills in the RMP to test the effects of diver presence on turtle behavior, and collected sea turtle sightings surveys from dive operations in the RMP to determine if dive site use impacted sea turtle behaviors. This information has provided a baseline from which new studies can be developed on turtle interactions with divers, hawksbill ecology, home range analysis, and turtle photo ID. These results will enable RMP managers, conservation agencies, and government officials to design more effective management strategies for areas accessible to SCUBA diving, and implement better protocols for turtle-diver interactions in marine protected areas (MPAs). This project was carried out in collaboration with the RMP. For details on all methods, results, and implications of these studies, see Hayes et al. (in press) and Baumbach and Dunbar (in review).

This report has been furnished to all appropriate Secretariats, Ministries, and Departments of the Honduran Government, including SAG, DIGEPESCA, SERNA, DiBio, and ICF. Data from this report may be included in the annual report of Honduras to the Inter- American Convention for the Protection and Conservation of Sea Turtles (IAC) with appropriate credit cited.

METHODS

Study Area

Roatán is a 77 km island located approximately 52 km off the north coast of Honduras (16°20′24″N, 86°19′48″W). The Bay Islands, of which Roatán is the largest, form part of the Mesoamerican Barrier Reef complex. The Bay Islands were once one of the seven major historical hawksbill nesting areas in the Caribbean, (Long 1774, Meylan 1999, McClenachan et al. 2006), yet to date, local hawksbill populations in the area are poorly understood (Dunbar and Berube 2008). The Roatán Marine Park (RMP) is a community-based MPA covering a network of coastal coral reefs and mangrove estuaries extending approximately 13 km from the towns of West Bay, West End, and Sandy Bay, and around the western tip of Roatán (Fig. 1).

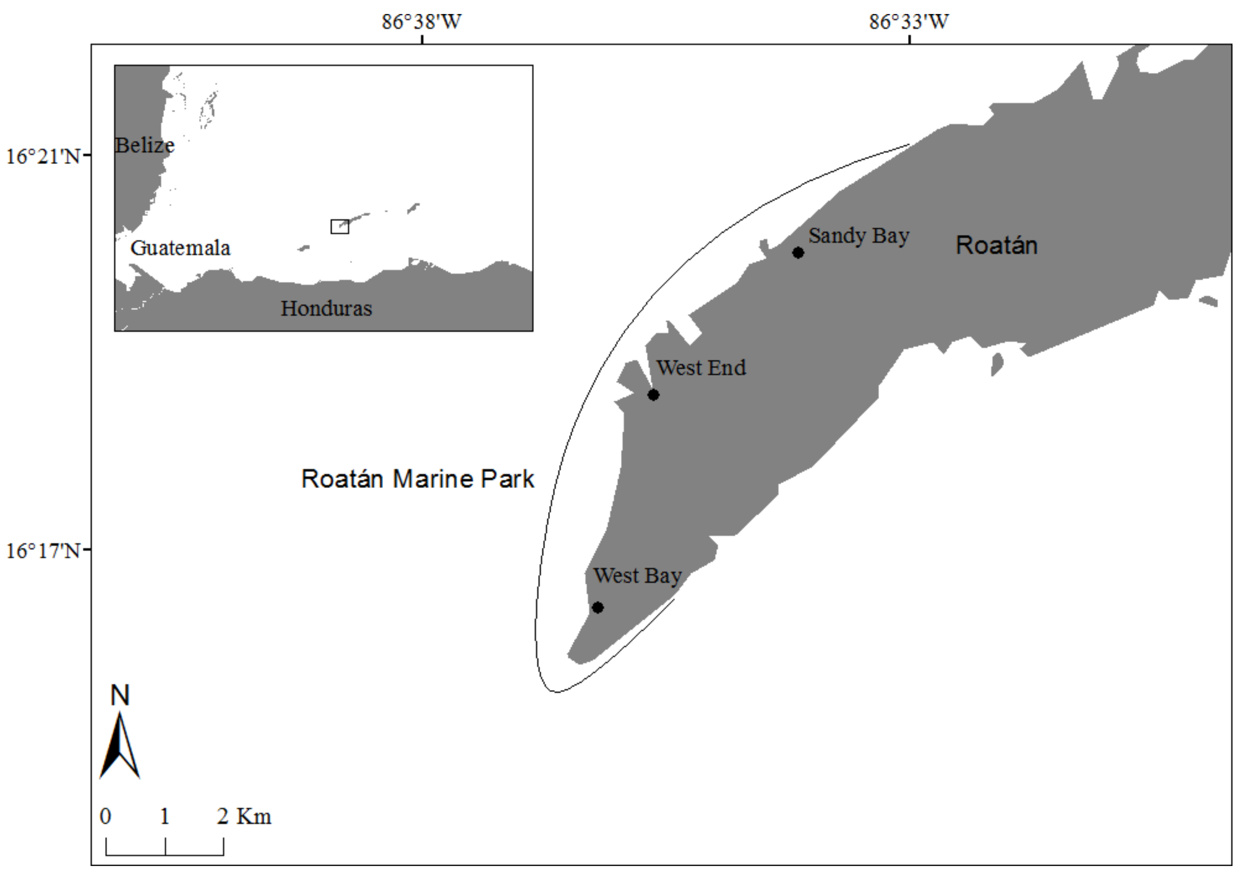

Figure 1. Map of Roatán and the Roatán Marine Park, Bay Islands, Honduras. Black line indicates the approximate area of the Roatán Marine Park. Inset shows regional location of Roatán. Source: Hayes et al. (in press).

Within the RMP, the reef crest lies approximately 92 meters off shore and slopes gradually for 2.2 km before dropping off steeply (> 130 m) at the reef wall (Gonzalez 2013). Bathymetry is varied, composed primarily of hard corals from the families Faviidae, Milleporidae, and Pocilloporidae; soft corals from the families Gorgoniidae and Plexauridae; sponges of Chondrillidae, Geodiidae, and Petrosiidae; turtle grass (*Thalassia testudinum*); and sandy substrate (Dunbar et al. 2008, Berube et al. 2012). Diving tourism within the RMP has increased substantially within the last 15 years and is concentrated in the towns of West End and West Bay (Doiron and Weissenberger 2014).

Turtle Sightings and Dive Logs

From June 9 to August 29, 2014 we distributed weekly survey forms to dive operators in the West End. On each data sheet, divers recorded the site, date, name of the diver logging the information, depth of sighting (meters), species, life stage of the turtle (adult or juvenile), and number of individuals sighted. All values that divers gave in imperial units were converted to metric. Participants were given identification sheets (in both English and Spanish) to aid in species identification and promote awareness. When species were unable to be identified, they were assigned to the "unknown" group for analysis. We collected data sheets 1–2 times per week as able, combined this data with turtle sightings from our own dives, and input the information into a Microsoft Excel (2003) file for analysis. Over the duration of the study period, we also collected daily dive logs from dive operations within the West End to calculate monthly dive site use. On each dive log sheet, divers recorded date, site visited, time of day (if available), and number of divers. To avoid pseudoreplication we only analyzed the point-of-entry dive site for drift dives.

In-water Observations

We conducted continuous focal and video in-water observations of hawksbills using modified methods from Dunbar et al. (2008) and von Brandis et al. (2010) during dive trips between 09:00 and 16:00 hrs. We followed each individual as long as possible and recorded observed behaviors using an underwater camera (Olympus Stylus Tough-8000 12 MP with Ikelite underwater camera housing) and video camera (GoPro Hero 3+ Black Edition with underwater housing; GoPro Inc., San Mateo CA). We recorded water depth (m) using a standard wristworn dive computer (Leonardo; Cressi Inc., Genova, Italy), and start and stop time (to the nearest second) for all observed activities using a water resistant watch (Expedition T4005; Timex Group USA Inc., Middlebury, Connecticut). We recorded notes of observations underwater using underwater paper.

All behaviors were characterized into six solitary and two social behavior categories. The six solitary behavior categories included swimming (active movement along the bottom, through the water column, or near the surface), resting (coming to a stationary position on the sea floor), surfacing (to breathe), investigating (active searching for food material indicated by a pause in swimming and active examination of nearby material), eating (the intentional ingestion of a substance), and scratching (on coral or object) (as per Dunbar, et al. 2008). The two social behavior categories included reacting (physical response to diver presence) and intraspecific interacting (reacting to presence of other turtles). In addition to measuring time, we also recorded the total number of occasions a turtle engaged in each behavior and defined this value as the number of bouts for a given activity. When visibility permitted, we counted the number of times a turtle lifted its head out of the water as a proxy for total number of breaths taken at the surface (as per Von Brandis et al. 2010).

As a control for diver interaction, we began all observations (when possible) by recording turtle behaviors for approximately 5 min with divers keeping at an approximately constant distance of 3–5 m from turtles (Meadows, 2004). We defined this position as the baseline position for divers. To test if diver approach affected a change in the amount of time turtles engaged in specific behaviors, we instructed different sized groups of 1–4 divers to slowly approach and observe each turtle. We defined diver approach as the intentional movement of divers from baseline position to within 1–2 m of sea turtles. To remove user bias for choosing particular group sizes, we varied the test group size randomly on each dive. During diver-turtle interactions we recorded all relevant diver parameters, including the number of divers watching a turtle at the beginning and end of an interaction, the number of touches on a turtle by a diver, and the closest estimated distance a diver approached a turtle. We conducted repeated in-water observations for turtles (as able) to test for turtle habituation to diver presence. To test for repeat observations of the same turtle, we collected left, right, and dorsal facial photographs of all observed turtles and analyzed them with the Interactive Individual Identification System (I^3S): Pattern (Version 4.0.1; den Hartog and Reijns 2014) using methods as per Baeza et al. (2015) (Figure 2).

Figure 2. I^3S photo analysis using standardized reference points (blue) and target region (green) for (A) left lateral, (B) right lateral, and (C) dorsal view aspects of hawksbill (*Eretmochelys imbricata*) sea turtles. Lateral reference points are located at the tip of the beak, the most inferior point of the eye, and the farthest edge of the postorbital scales. Dorsal reference points are located at the tip of the beak, the middle of the frontoparietal scale, and the most inferior point of the dorsal parietal scales.

RESULTS

Sightings and Dive Logs

We collected turtle sightings information from 14 dive operations in the West End. Dive operations recorded 701 dives at 46 sites between June 9 and August 29, 2014. Ten survey entries did not specify either the dive site or date, and were excluded from analysis. On the majority of occasions (n = 445), one turtle was seen, and 26 dives recorded no turtle sightings (Table 1). A total of 666 hawksbills, 420 greens (*Chelonia mydas*), four loggerhead (*Caretta caretta*), and 22 unknown turtles were reported during the study. Of the hawksbills reported, 393 (59%) were reported as adults and 273 (41%) as juveniles. Of the greens reported, 282 were reported as adults and 138 as juveniles.

Table 1. Turtle sightings frequencies in the Roatán Marine Park.

Occasions	Turtles	Occasions	Turtles
26	0	7	6
445	1	3	7
133	2	2	8
48	3	1	9
23	4	1	10
11	5	1	12

We compiled 648 dive logs involving 3092 divers between June 9 and August 29. A total of 3092 divers were logged as diving during that time period. The mean number of divers per dive was 5.0 ± 0.3 SE and mean hawksbill sightings rate per dive was 1.0 ± 0.1 SE. Turtle sightings distributions throughout the RMP did not vary with the total number of divers per visit at each site over the 82-day period, suggesting that hawksbill abundance in the RMP is independent of diving pressure. Spatial distribution of sightings and divers indicated that divers tended to make more sightings between West End and West Bay and fewer sightings between West End and Sandy Bay (Fig. 3). Sightings survey effort was unevenly distributed over 3 months, with peak intensity occurring in July (Fig. 4). This distribution significantly correlated with total turtle sightings (Fig 3; $n = 46$, $r_s = 1.00$, $p < 0.01$).

Turtle eating, swimming, and breathing behavior, did not differ with dive site use, suggesting that turtle behavior is independent of diving pressure within the RMP. These results are supported by Slater (2014) who found that green turtle (*Chelonia mydas*) foraging behavior was not correlated with tourist abundance. However, because our sightings and dive log survey results are limited to a single time period (June–August, 2014), our results may represent seasonal trends in turtle sightings and diving pressure.

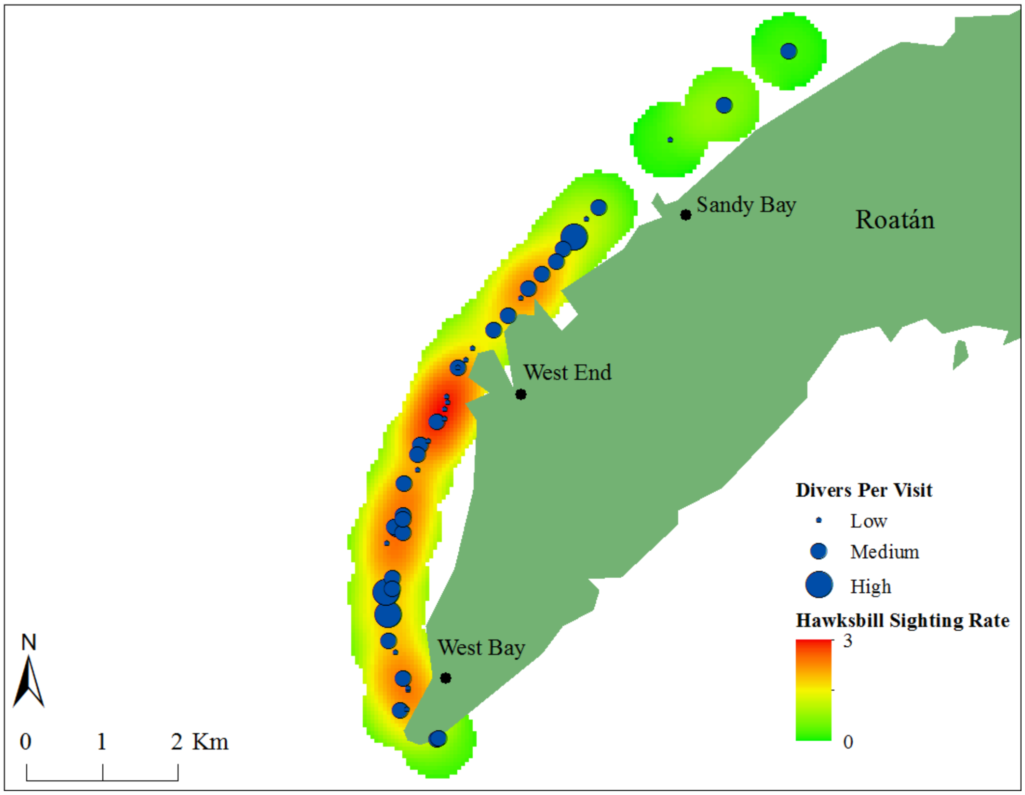

Figure 3. Hawksbill sightings rate and diver density for 46 dive sites in the Roatán Marine Park. Size of dots indicates mean number of divers per visit from two dive operations to each site over an 82 day period. Color gradation indicates fixed kernel density (1 km) estimate of hawksbill sightings rates from 14 dive operations. Hawksbill sighting rates are associated with dive site coordinates. Source: Hayes et al. (in press).

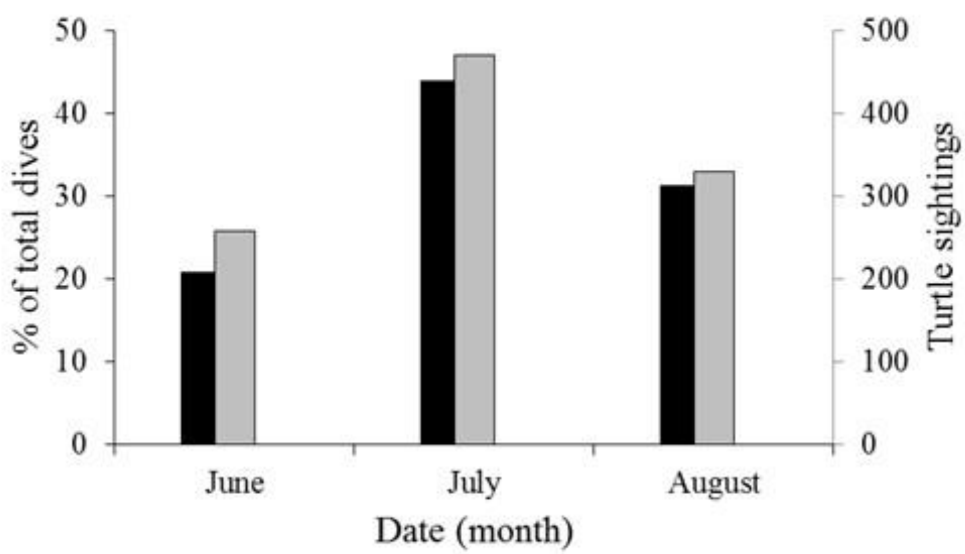

Figure 4. Monthly survey effort and turtle sightings. Black bars (left vertical axis) are the percentage of total dives from sightings survey occurring in each month. Grey bars (right vertical axis) are the total turtle sightings for each month. Scale: 500 max.

In-water Observations

From 12 June to 2 September, 2014, we conducted 6092.0 min of surveys at 23 sites in the Roatán Marine Park. We devoted 1027.3 min (16.9% of total survey time) to conducting in-water observations of 61 juvenile hawksbills. The average number of hawksbills observed per dive was 0.7 ± 0.1. We obtained repeated observations of 11 turtles, with nine individuals observed twice and two individuals observed three times. Total initial observation time was 823.9 min. and total time for repeated observation (not including initial observation time) was 203.4 min. All re-observed turtles were found within five sites of their initial observation (Fig. 5).

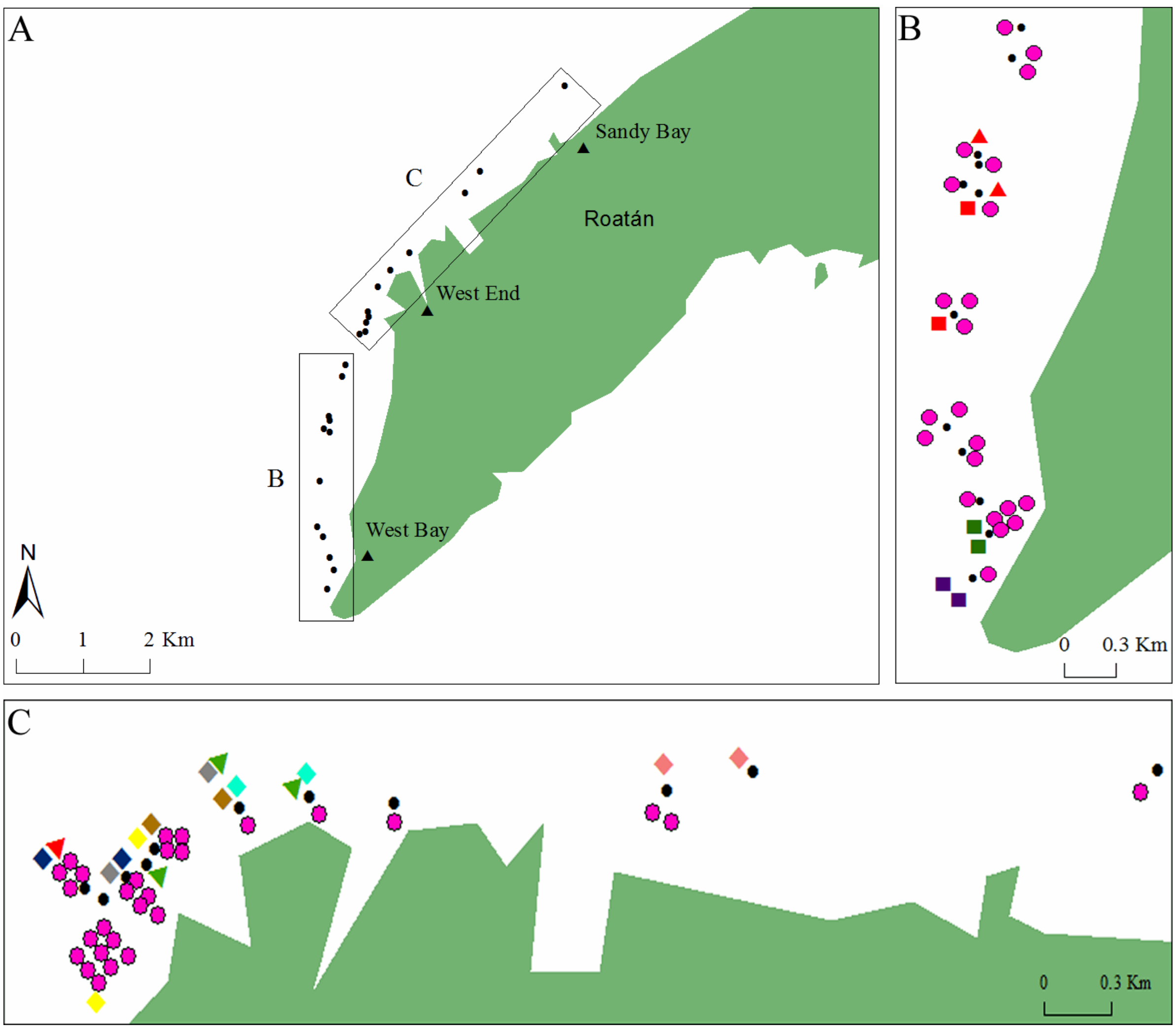

Figure 5. (A) In-water observation locations from 61 hawksbills in the Roatán Marine Park between (B) West Bay to West End (*n* = 30) and (C) West End to Sandy Bay (*n* = 31). Black dots: dive sites (*n* = 23). Pink circles: single observations of individuals (*n* = 50). Colored squares: Individuals observed twice (*n* = 18). Colored triangles: Individuals observed three times (*n* = 6). All observations are associated with the geographic coordinates of the closest dive site. Source: Hayes et al. (in press).

Mean turtle observation depth (n = 61) was 14.3 ± 1.0 m (range 4.6–39.6 m). Mean observation time per turtle was 13.3 ± 7.5 min (1.2–36.0 min). During 823.9 min of observations, swimming was the most commonly observed behavior. Mean turtle swimming time was 7.8 ± 0.7 min (0.0–25.5), and represented 57.9% of all observation time (Table 2). Turtles spent a mean of 0.5 ± 0.1 min breathing (0–3.6 min) and took a mean of 3.3 ± 0.1 breaths (n = 203, 0–12) at the surface. Mean number of divers (n = 183) observing turtles was 3.0 ± 0.2 (1–8). Although 21 turtles (34.4%) exhibited an obvious reaction (indicated by a rapid change in turtle swimming direction or activity) when approached by divers, 40 (65.6%) did not. On three occasions, we observed intraspecific interactions between hawksbills. Twice, two hawksbills approached each other, circled for several seconds and then swam away, and once, two individuals pressed their left ventral postocular and tympanic scales flat against each other, circled around each other for 26.0 seconds, and then swam in different directions.

Table 2. Behavior categories, mean time (min) displaying behavior, time range of each activity, and proportion of total observation time of each activity for 61 hawksbills in the Roatán Marine Park. Total observation time: 823.9 min. Source: Hayes et al. (in press).

Behavior	Mean time of each activity ± S.E.	Range (min)	Proportion of observation time
Swimming	7.8 ± 0.7	0.0 – 25.5	57.9
Eating	2.2 ± 0.5	0.0 – 15.9	16.5
Investigating	2.2 ± 0.4	0.0 – 12.8	16.3
Breathing	0.5 ± 0.1	0.0 – 3.6	4
Reacting	0.5 ± 0.2	0.0 – 7.0	3.4
Interacting	0.2 ± 0.1	0.0 – 5.8	1.4
Resting	0.1 ± 0.1	0.0 – 3.0	0.4
Scratching	0.1 ± 0.1	0.0 – 0.5	0.1

Similar to Dunbar et al. (2008), we found that swimming was the most commonly observed behavior in hawksbills (57.9% of total observation time). However, unlike Dunbar et al. (2008), we found that eating was the second most commonly observed behavior (16.5%). Whereas Dunbar et al. (2008) conducted observations in an area outside the RMP, where sea turtle protection is not enforced, our study was conducted within the RMP, where daily patrols regulate sea turtle poaching and harassment. Studies of state-dependent risk-taking in green turtles by Heithaus et al. (2007) in Shark Bay, Western Australia, indicated that turtles will preferentially forage closer to bank edges in safer, yet lower foraging quality micro-habitats, when tiger shark (*Galeocerdo cuvier*) populations are high, and move farther from bank edges into areas with better foraging quality when shark population levels are reduced. If foraging behavior in hawksbills is similar to predation-dependent foraging behavior in green sea turtles, it is possible that turtles within the RMP spend a larger proportion of time eating than turtles outside the RMP due to reduced harassment and predation risk within the RMP.

In corroboration with the findings of Slater (2014), we found that hawksbills within the RMP spent less time eating, investigating and breathing during diver approach (Fig. 6). However, contrary to Meadows (2004), we found that human approach had no significant effect on hawksbill behavior bouts. In his study, Meadows (2004) concluded that the frequency change in the number of behavior bouts was likely a consequence of turtles switching rapidly between behaviors to avoid snorkeler attempts to chase, touch, or ride them. Unlike Meadows (2004), however, we did not observe any attempts by recreational divers to chase, touch, or ride turtles. Thus, we suggest that turtles in our study were affected differently by human approach because divers followed strictly enforced policy prohibiting the harassment of sea turtles. Instead, we hypothesize that hawksbills within the RMP are habituated to diver presence and interested in diver activity, leading them to engage in less investigating, eating, and breathing behavior when divers are present.

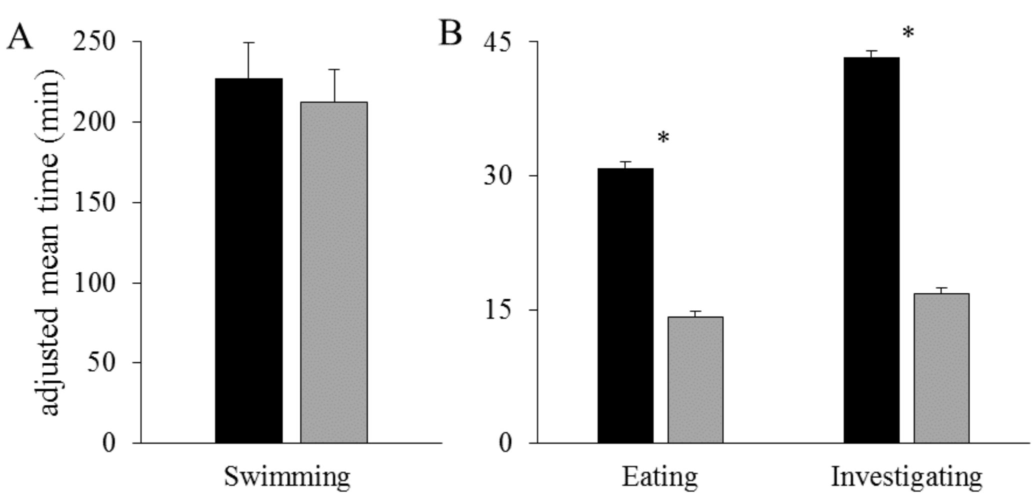

Figure 6. Adjusted mean time (min) + 1 SE that turtles (n = 53) engaged in (A) swimming behavior, and (B) eating and investigating behavior when divers were at baseline position (black bar) and during diver approach (grey bar). Time values are adjusted by the total time when divers were at baseline position (285.5 min) and the total time during diver approach (538.4 min). Asterisk (*) indicates $p < 0.05$. Source: Hayes et al. (in press).

These results, as well as multiple other examples, suggest that diver habituation may negatively impact marine macrofauna behavior. On multiple occasions we observed groupers (Epinephelinae) alter their normal foraging behaviors and follow spear-hunting divers, in order to take advantage of speared fish as an accessible food resource. Similarly, we were informed by multiple dive operations, that divers will feed groupers at certain dive sites, causing large numbers of groupers to periodically abandon regular foraging behaviors and form large aggregations at those sites (Hayes, personal observation). Moreover, Titus et al. (2015) found that cleaning behavior of reef fish on a heavily dived reed in Utila, Honduras was suppressed > 50% when divers were nearby, and concluded that diver presence could reduce the fitness and lifespan of coral reef fish communities. These studies suggest that habituation of marine fauna to recreational divers can cause unintended behavioral changes over time. It remains unknown, however, if recreational diving may have a cumulative effect on turtles over time. If long-term changes in behavior are energetically expensive for turtles, divers may negatively impact sea turtle growth and fecundity, as suggested by Meadows (2004), and may cause changes to short- and long-term fitness levels (Amo et al. 2006, Titus et al. 2015).

RECOMMENDATIONS

Recommendations for the Roatán Marine Park

Recreational diving within the RMP has increased substantially in the last 15 years and continues to increase annually (Doiron and Weissenberger 2014). Current rules governing recreational diver interactions in Roatán, Honduras are not well developed and poorly enforced (Doiron and Weissenberger 2014) suggesting that new, scientifically-based regulations should be implemented to properly monitor recreational diver interactions with sea turtles. Based on the results of the current study, we provide the following recommendations for the RMP.

Long Term Dive Log Reports from Dive Operations in the RMP

We recommend that the RMP should implement regulations requiring that dive operations within Sandy Bay, West End, and West Bay keep daily dive logs and report those logs to the RMP on a regular basis. In our current study, we found that many dive operations did not record daily dive logs or were unwillingly to allow us to access their dive logs. Better exchange of data and transparency among dive operations, the RMP, and researchers working with the

RMP would allow more powerful analyses to be conducted and more effective regulations to be implemented. Requiring dive operations within the RMP to report daily dive logs on a regular basis, would allow RMP officials to measure diving pressure at different dive sites throughout the RMP over time, and create regulations that are specific to particular areas heavily affected by recreational diving.

Long Term Sea Turtle Sightings Surveys in the RMP

We also recommend that the RMP begin a long term volunteer dive sightings program in partnership with ProTECTOR Inc., with dive operations in Sandy Bay, West End, and West Bay. A long term turtle sightings program in the RMP would enable RMP officials to measure changes in relative sea turtle populations over time and, when combined with long term dive log surveys, would allow regulations to be implemented that specifically target the impacts of recreational diving on sea turtles within the RMP.

In order for long term sea turtles sightings surveys to be effective, divemasters within the RMP require training in proper sea turtle identification and data recording techniques. In the current study we found, similar to Bell et al. (2009) and Williams et al. (2015), that divemasters within the RMP tended to record dive sightings only when a turtle was observed during a dive, and forgot to fill in the form when no turtle was sighted. Ensuring that divemasters reported occasions on which zero turtles were sighted would allow ProTECTOR Inc. and RMP officials to compare rates of turtle sightings at different sites over time, and determine if turtle populations in specific areas are increasing or decreasing. We also found that widespread misidentification of turtle life stage was a common problem for divemasters in the RMP. Similar to the findings of Williams et al. (2015), divers in the current study tended to overestimate life stage of sea turtles, and misidentify juveniles as adults. We also found that dive operations tended to record sightings sporadically and often only when specifically asked by researchers or RMP officials. To increase the accuracy and efficiency of dive sightings surveys, **we recommend** that a single divemaster per dive excursion update sightings records immediately following each dive and turn in a weekly dive sightings report to the RMP office. **We also recommend** that the RMP work in conjunction with ProTECTOR Inc. to conduct active training workshops for divers on proper sea turtle identification and data recording.

Long Term Photo Identification Survey of Sea Turtles in the RMP

We recommend that RMP officials participate with ProTECTOR Inc. in long term turtle photo-identification surveys in the RMP to identify and track the movements of individual sea turtles within the RMP. If implemented over a long period, photo-identification surveys would allow project managers to estimate total population numbers of local green and hawksbill populations, monitor changes in populations over time, and re-identify individuals migrating to and from nesting beaches and foraging areas. This information will allow RMP mangers and ProTECTOR Inc. to create and enforce effective policies to manage observed changes in sea turtle populations within the RMP.

Habitat Assessment, Diet Analysis, Heavy Metal, and Home Range Studies

We recommend that the RMP work with ProTECTOR Inc. and local communities to conduct additional studies of hawksbill sea turtles within the RMP in order to develop a working knowledge of local sea turtle population health and habitat use in relation to human activity and environmental variability. Specifically, **we recommend** that long-term habitat assessments, diet analysis, and home range studies be conducted within the RMP to determine if changes in dive site use and human behavior negatively impact sea turtle foraging habitat and lead to changes in sea turtle foraging patterns over time. Additionally, **we recommend** that additional pollution, blood, and heavy metal studies be carried out on hawksbills in the RMP to test for potential physiological effects on sea turtles species from human pollution and sea turtle parasites. To test for effects of sea turtle handling by researchers on sea turtle behavior and health, RMP managers should work with ProTECTOR Inc. to implement the above studies on several individual turtles identified using a photographic identification system, and measure differences in sea turtle behavior and health over time.

Recommendations for Marine Protected Areas

We recommend that management officials in marine protected areas (MPAs) around the world implement research projects using in-water observations and turtles sighting surveys to quantify the impact of recreational diving on different species of sea turtles. Management officials in areas with high levels of regular diving tourism, such as marine protected areas in the Northern Red Sea (Zakai and Chadwick-Furman 2002), Bonaire (Hawkins et al. 1999), and Grand Cayman (Tratalos and Austin 2001), should be particularly concerned with the potential negative impacts of large groups of recreational divers on sea turtle behavior, and, in conjunction with sea turtle research, design management regulations to mitigate these impacts.

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