Aquatic Mammals 2017, *43*(6), 661-672, DOI 10.1578/AM.43.6.2017.661

Changes in Bottlenose Dolphin (*Tursiops truncatus*) Distribution and Behavior in the Drowned Cayes, Belize, and Correlation to Human Impacts

Jazmin Garcia, Caryn Self-Sullivan, and Nicholas A. Funicelli

Halmos College of Natural Sciences and Oceanography, Nova Southeastern University, Dania Beach, FL, USA
E-mail: garciajzm@gmail.com

Abstract

Human activity can greatly influence the behavior and distribution of bottlenose dolphins (*Tursiops truncatus*). This project focused on the distribution and behavior of bottlenose dolphins in the Drowned Cayes, Belize. Prior to the 2000s, the area was relatively undeveloped and undisturbed and had minimal human activity. Since 2000, fish camps, small resorts, and cruise ship tourism have flourished in the area. This has caused an increase of over 800,000 visitors from 1998 to 2006. Boat-based survey data were collected from 2005 to 2015 and compared to results from surveys conducted in 1999-2000. Total dolphin observation time as a percentage of total survey time was 17.2% in the 1999-2000 dataset and 10.8% in the 2005-2015 datasets. This decrease in observation time suggests that the dolphin population in the Drowned Cayes has decreased since the late 1990s. However, these values could be influenced by survey methods. In 2015, cruise ship presence in the area was also recorded. Eighty-nine percent of the total observation time for 2015 occurred on days for which there were zero cruise ships present, suggesting that dolphins may be avoiding the area when cruise ships are present. Foraging was the most frequently observed behavior in both 1999-2000 and 2005 to 2015 suggesting that the Drowned Cayes is used as a foraging area. That said, the percent of foraging activity was significantly higher in 1999-2000 (86.3%) than in 2005 to 2015 (57.4%), having dropped by 28.9%. Interestingly, there was a 23.6% increase in traveling behavior between 1999-2000 (9.2%) and 2005 to 2015 (32.8%). These behavioral changes could potentially be linked to increased human activity or other unidentified factors. Examining observed changes in behavior increases knowledge of this species in the study area and can provide insight for improved local management of this small dolphin population.

Key Words: Belize Barrier Reef Lagoon System, ecotourism, behavior, cruise ships, mother–calf pairs, Swallow Caye Wildlife Sanctuary, conservation, human impacts, bottlenose dolphin, *Tursiops truncatus*

Introduction

Many studies have shown that human activity causes increased risks and changes in behavior in bottlenose dolphins (*Tursiops truncatus*) (Constantine, 2001; Nowacek et al., 2001; Samuels & Bejder, 2004). However, much of this research occurs in sites of high human activity. There is a growing interest and need to research and expand our knowledge of dolphin populations in areas that have only recently experienced increased human development and tourism like the Drowned Cayes, Belize. These dolphins may be susceptible to changes in behavior.

Prior to 2000, the area surrounding the Drowned Cayes, including Belize City, was relatively undisturbed with minimal human activity (Petersen, 2001). In the 1980s, Belizean tourist facilities expanded in response to an increasing cruise ship industry and, since 1998, tourism in Belize has increased exponentially (Duffy, 2000; Self-Sullivan, 2008). From 1998 to 2006, there was an increase of more than 800,000 visitors entering Belize via cruise ships, with cruise ship tourism increasing 692% between 2001 and 2004 (Belize Tourism Board, 2007; Self-Sullivan, 2007). Belize City, which is 5 km from the Drowned Cayes, has become a very popular port for many cruise lines. Passengers often pass through the study area via tender and tour boats to reach snorkeling and diving destinations. Much of the activity that occurs within the Belize Barrier Reef Lagoon System (including the Drowned Cayes) consists of boat traffic. Human industries such as tourism and small-scale commercial fisheries harvesting

finfish, conch, and lobster from the various ecosystems (Petersen, 2001; Cho, 2005) are the source of this boat traffic.

As human activity increases, so does the need to research the potential effects of this on bottlenose dolphin behavior and habitat use. Previous studies in other locations have found that human presence reduces the occurrence of frequent dolphin behaviors and that dolphins will actively avoid areas of high human traffic (Nowacek et al., 2001; Lusseau et al., 2003; Constantine et al., 2004). Some dolphins will cease to rest or forage when humans are present (Constantine, 2001), while others have been shown to travel away or take longer dives to avoid human activity (Nowacek et al., 2001; Lusseau et al., 2003).

The overall goal of this study was to document changes in behavior and habitat use by the Drowned Cayes bottlenose dolphin population that might be correlated to increased human activity in the area. We compared boat-based survey observations conducted from 2005 to 2015 to Petersen's (2001) 1999-2000 surveys to determine whether behavior and habitat use changes have occurred during this gap in research that coincides with a time of exponentially increased human activity in Belize.

Methods

Study Area

The Drowned Cayes is a 15-km-long chain of mangrove islands within the Belize Barrier Reef Lagoon System (Figure 1) (Petersen, 2001; LaCommare et al., 2008). It is located approximately 5 km east of Belize City and 3 km west of the Belize Barrier Reef. The Drowned Cayes is a complex area of high productivity, characterized by seagrass beds, mangrove islands, and patch reefs. Most of the Drowned Cayes is uninhabitable due to the lack of dry land; however, over a half a dozen sites have been dredged and filled to develop fish camps and small resorts.

Belize falls between subtropical and tropical conditions. The dry season runs from December to April, and the wet season runs from May to November. Along the coast, the maximum temperature is 31° C in July and the lowest is 19° C in January (Murray et al., 2003). Water depth around the Drowned Cayes is shallow, with a maximum depth of 5 m, except for the eastern channel that reaches up to 50 m. Shallow channels, referred to as bogues (Ford, 1991), run into and between the cayes. Little tidal variation exists; the tidal range is less than 0.3 m (Petersen, 2001; LaCommare et al., 2008).

The study area covers approximately 200 km^2. The two most northern mangrove islands within the Drowned Cayes lie within the Swallow Caye Wildlife Sanctuary (SCWS). The SCWS was established in July 2002 after local manatee tour operators pushed for a Marine Protected Area to minimize impacts on marine habitats near Belize City. The sanctuary encompasses 3,630 ha of sea grass beds, deep channels, and mangrove islands (Self-Sullivan, 2008).

The bottlenose dolphin population is small and finite based on survey data collected from 1997 to 1999 (Kerr et al., 2005). During these surveys, Kerr et al (2005) photographically identified 115 dolphins and calculated that roughly 30% were residents. The Drowned Cayes dolphin population appears to have very little overlap with surrounding populations. Turneffe Atoll, for example, is an offshore atoll, located 16 km from the Drowned Cayes. Like the Drowned Cayes, it contains coral reefs, sea grass beds, and mangroves. Despite its proximity to the Drowned Cayes, there have been only three confirmed photographic matches of overlapping individuals to date (Hancock, 2007). Group sizes are relatively small for this population with 2.7 and 2.9 dolphins per sighting (Petersen, 2001; Kerr et al., 2005). A high number of calves have previously been observed, suggesting that the area is used as a nursery (Petersen, 2001; Kerr et al., 2005). Most of the study area is used for foraging, particularly in the mangrove channels (Petersen, 2001). Although there are no records of prey preferences for this dolphin population, the observed foraging behavior, small group sizes, and similarities to the Turneffe Atoll population suggest that dolphins in this area feed on non-schooling prey. Non-schooling prey in the Turneffe Atoll include species from the families of Apogonidae (cardinalfish), Congridae (congers), Lutjanidae (snappers), Mugilidae (mullets), Sciaenidae (drums and croakers), Sparidae (porgys), Batrachoididae (toadfish), and Loliginidae (reef squid).

Data Collection

Boat surveys were completed from May through September throughout 2005 to 2015. Our surveys fall within the same monthly range as Petersen (2001), who completed surveys from April to July 1999 and August to November 2000. However, all of our surveys occurred during the wet season (May to November); whereas Petersen's (2001) surveys were divided evenly between dry and wet seasons (77 and 72 surveys, respectively).

Surveys were conducted on both the east and west sides of the mangrove islands and through the bogues, Swallow Caye, Stimpy's Lagoon, and Gallows Reef. Surveys occurred in the morning and early afternoon between 0800 and 1600 h. This is slightly different than Petersen (2001) who completed two surveys per day: 0900 to 1200 h and 1400 to 1700 h. Skiffs (8.5 to 9 m

long) equipped with a 175-hp outboard engine were used for surveys with an average speed of 8.5 km/h maintained throughout the surveys. All surveys were completed with at least four people onboard. The study area was divided into subareas—west or east coast or individual bogues—for daily surveys. The surveys were organized so that both coasts and all bogues were surveyed at least once per survey season to ensure that the entire study area had been surveyed. Once the entire study area was surveyed, repeated subareas were selected in a randomized manner.

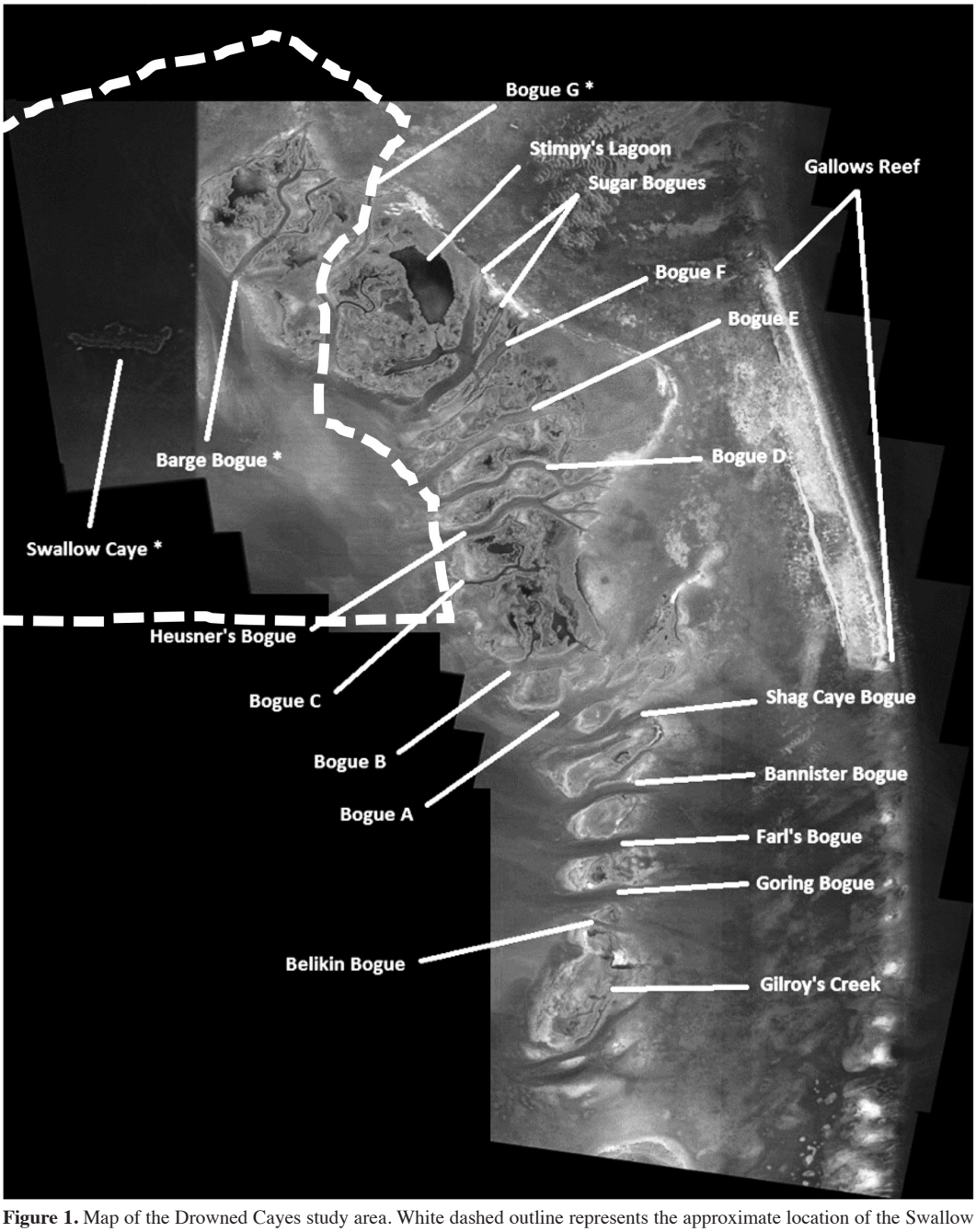

Figure 1. Map of the Drowned Cayes study area. White dashed outline represents the approximate location of the Swallow Caye Wildlife Sanctuary (SCWS); sites with asterisks (*) are located within the SCWS (*Google Maps* 2017).

To compare our results to Petersen (2001), all efforts were made to simulate the methodology and data collection. For each survey, the date, area or bogue name, beginning and ending positions (GPS coordinates), times, sea state, cloud coverage, swell height, and the amount of precipitation were recorded. Bogues were surveyed by traveling slowly (4 to 8 km/h, depending on current) from one end to the other. Once a dolphin was sighted, we slowed to minimize the effect of our presence, following a line of travel parallel to the dolphin's path. We observed the dolphin(s) long enough to determine behavioral state and to take photos of the dorsal fin(s) but not long enough to conduct focal follows. The date, beginning and ending time of observation, GPS position, group size, number of calves, and other comments (e.g., boats present, identification of dolphins, etc.) were recorded for each sighting. Behavioral state of the dolphin groups was categorized as "Forage," "Rest," "Social," "Travel," or a "Combination" of these and were based on the definitions provided by Petersen (2001). Once the data were recorded, a new survey was started from the end of the previous sighting.

Surveys from 2005 to 2012 were focused on both manatees and dolphins; therefore, some time was spent observing manatees. However, while manatee sightings occurred, at least one person on the boat would keep scanning the surroundings for dolphins. Surveys conducted in 2015 focused solely on dolphins but we also began to record the number of cruise ships that were docked in the port of Belize City.

Data Analysis

Survey times, observation (sighting) times, and group size for all surveys and sightings were added together to calculate total survey time, total observation time, and total number of dolphins sighted, respectively. If more than one sighting occurred during a survey, the survey time was only included once to avoid doubling survey durations. Sighting time and dolphin group sizes were counted as individual and separate sightings. For opportunistic dolphin sightings ($n = 10$) (i.e., sightings outside of official boat surveys on the way to or from our research station), overall survey times were recorded as equal to sighting times to not include off-effort time in our analysis. Behaviors were categorized as one of four behavioral states (i.e., forage, rest, social, and travel), a combination of two or more states, or undetermined. For sightings where the exact time when the behavioral state changed could be determined, the sighting was split to distinguish the different durations for each behavioral state. When more than one behavioral state was observed during a sighting but no exact time for the behavior change was recorded, then the sighting was categorized with a behavioral state as a combination. Those sightings where dolphins were lost before behaviors could be determined or whose data sheets did not include behavioral state were categorized as "Undetermined."

Total observation time was calculated as a percentage of total survey time for the entire dataset and for each year individually. Similarly, behavior duration (i.e., total time spent on each behavior) was calculated as a percentage of total observation time. Total observation time was also calculated for the entire dataset and for each year. To determine whether one year differed significantly from the others in terms of behavior duration, a Fisher's exact test was performed.

Comparison of 1999-2000 Data vs 2005-2015 Data

Number of hours on the water, number of hours observing dolphins, number of sightings, number of dolphins sighted, and average number of dolphins per hour were calculated using the same methods as Petersen (2001), and values were compared between datasets. To determine if there was a significant difference in the number of sightings between datasets, the number of sightings were divided by the number of hours on the water for each dataset, and a two-sample test for equality of proportions ($\alpha = 0.05$) was performed.

Dolphin sightings which were behaviorally categorized as "Undetermined" were removed from the dataset, and only sightings for which behavioral activity was identified were used for the remaining comparisons. The sightings were separated by behavioral state: forage or combination, rest or combination, social or combination, or travel or combination. Similar to Petersen (2001), sightings that involved a combination of behaviors were included in both groups but were not counted as two separate sightings. For example, a sighting involving forage and social behaviors was included in both the forage and social groups but only counted as one sighting in the overall total. The percentages for each group (number of sightings involving the behavior/total number of sightings) were calculated. The results were compared to Petersen's (2001) calculations, and a chi-square test ($\alpha = 0.05$) was performed for each behavioral state to determine if results were significantly different between datasets.

Sightings Distribution

Two sightings distribution maps were created for the 2005-2015 time period—one with all the sightings and the other for only the behaviorally classified sightings. The maps were created using *Google Maps* and by entering the latitude and

longitude collected for each sighting. Sightings that had latitude and longitude points missing were omitted from the maps. The behaviorally classified sightings map included only sightings for which behavior activity was identified (i.e., not categorized as "Undetermined") to compare with Petersen's (2001) behaviorally classified sightings distribution map. All maps include dashed outlines to mark the approximate location of the SCWS. We calculated the number of sightings per hour for sightings within the SCWS and compared it to the number of sightings per hour outside the SCWS by performing a two-sample test for equality of proportions ($\alpha = 0.05$).

The behaviorally classified sighting maps were compared side by side to determine if there were any drastic differences in the distribution of dolphin sightings between time periods. This comparison was done qualitatively. The SCWS was established in 2002 after Petersen (2001); therefore, we were unable to calculate a value for the number of sightings per hour or the number of dolphins sighted per hour within/outside SCWS for the 1999-2000 data.

Results

Survey Summary

There was a total of 85 surveys completed from 2005 to 2015. Field expeditions were not completed in 2013 and 2014, and survey data were unavailable for 2008. A total of 228.9 h was spent on the water, yielding a total of 74 dolphin sightings. Of this time, 24.8 h was spent observing dolphins, which accounted for 10.8% of total survey time. A summary of total observation time as a percentage of total survey time for each year is provided (Table 1). A total of 192 dolphins was observed, including resights. Of those, 39 individual dolphins were photographically identified, including seven that have been seen prior to this study and are part of the Drowned Cayes dolphin catalog from 1999. Most of the dolphins were found alone or in mother–calf pairs. The largest group size was eight in 2012. In 2015, no more than two dolphins were observed together at any one time.

The mean number of dolphins per sighting was 2.6 and ranged from one to eight. Of the 74 sightings, 34 were categorized as "Forage," two as "Rest," four as "Social," 19 as "Travel," two as a "Combination," and 13 as "Undetermined." The behavior duration or length of observation of each behavior as a percentage of total observation time are shown for each year individually and as a composite for all years (Figure 2). Almost every year had foraging as the predominant behavior. Social and rest were not observed every year, and yearly values were generally low. Travel behavior was observed almost every year; however, the percentage varied among years. Although all the years follow the general trend, there was a significant difference in observed behavior durations among years ($p = 0.000$). No one year was like another.

Ten surveys were conducted in August 2015 (51.6 h on the water). Eleven dolphin sightings were recorded such that 3.3 h were spent observing dolphins (6.4% of total survey time). Cruise ships were recorded on three survey days, and an island hopper was spotted on another day. On those 4 d, only one dolphin was observed for 5 min. Zero cruise ships were recorded on four other survey days. On those days, 1 d had no dolphin sightings, and 3 d had at least two sightings per day for a total of nine dolphin sightings. The nine sightings lasted a total of 2 h and 55 min, accounting for 89.0% of total observation time for 2015. Of the nine dolphin sightings, two involved one dolphin per sighting, and the other

Table 1. Summary for the 2005-2015 boat surveys. Survey data were unavailable for 2008, and field expeditions were not completed in 2013 and 2014. Observation and survey times were recorded in hours (hh) and minutes (mm). The percent value was calculated as the total observation time as a percentage of total survey time.

Year	Total observation time (hh:mm)	Total survey time (hh:mm)	Percent
2005	00:46	02:31	30.5
2006	08:07	98:46	08.2
2007	05:23	53:34	10.1
2009	02:17	05:38	40.5
2010	01:59	04:11	47.4
2011	01:18	07:15	17.9
2012	01:40	05:23	31.0
2015	03:17	51:35	06.4
Total	24:47	228:53	10.8

seven sightings involved two dolphins per sighting (mother–calf pairs).

Comparison of 1999-2000 Data vs 2005-2015 Data
Table 2 presents a summary of number of hours on the water, number of hours observing dolphins, number of sightings, number of dolphins sighted, average number of dolphins per sighting, number of sightings per hour, and number of dolphins sighted per hour for both datasets. The two-sample test for equality of proportions produced a value of $p = 0.282$ ($\chi^2 = 1.16$, df = 1) for number of sightings per hour; thus, the number of sightings per hour did not significantly differ between datasets.

Of the 74 dolphin sightings, behavioral assessments were made for 61 of those sightings (82.4%); 13 sightings were categorized as "Undetermined." The 61 behavioral assessments were compared to behaviors observed in 1999-2000, and the percentages of each behavior are illustrated in Figure 3. There was a significant difference in foraging between datasets ($\chi^2 = 5.81$, df = 1, $p = 0.016$) and for traveling between datasets ($\chi^2 = 13.26$, df = 1, $p \leq 0.001$). There was no significant difference in resting and social behavior between datasets ($\chi^2 = 0.32$, df = 1, $p = 0.572$ for rest; $\chi^2 = 2.90$, df = 1, $p = 0.088$ for social).

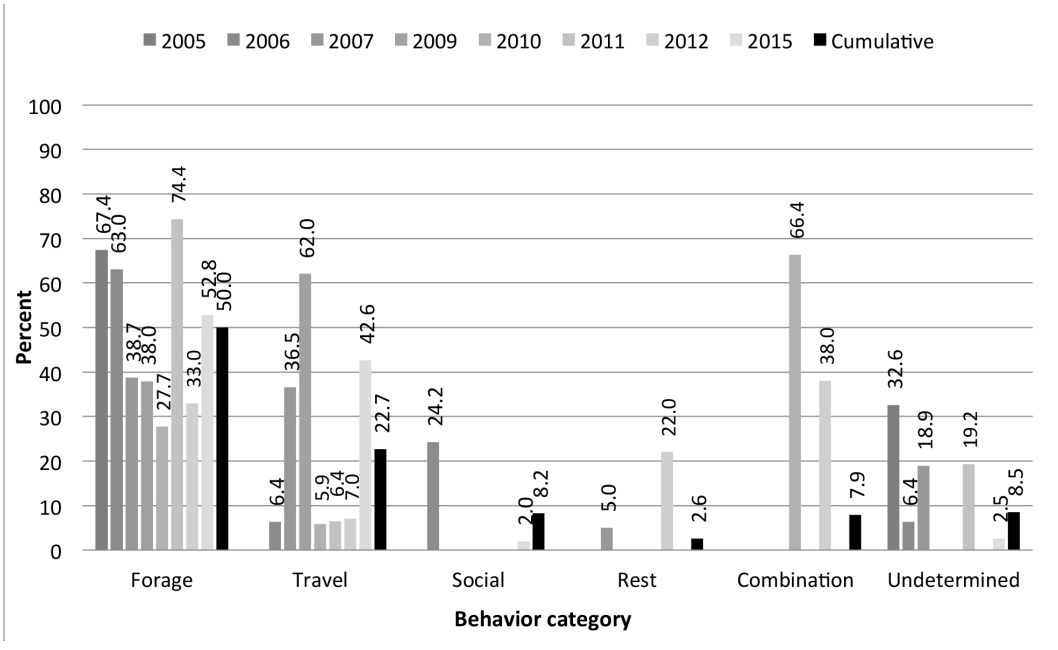

Figure 2. Behavior duration or observation times of each behavior as a percentage of total observation time in the 2005-2015 surveys, for each year individually, and as a composite for all years. Field expeditions were not completed in 2013 and 2014, and survey data were unavailable for 2008.

Table 2. Summaries for boat surveys completed during 1999-2000 and 2005-2015

	1999-2000	1999-2000 wet season	2005-2015
Number of hours on the water	463.3	226.3	228.9
Number of hours observing dolphins	79.8	--	24.8
Number of sightings (including resights)	169.0	72.0	74.0
Number of dolphins sighted	455.0	214.0	192.0
Number of sightings per hour	0.4	0.3	0.3
Average number of dolphins per sighting	2.7	3.0	2.6

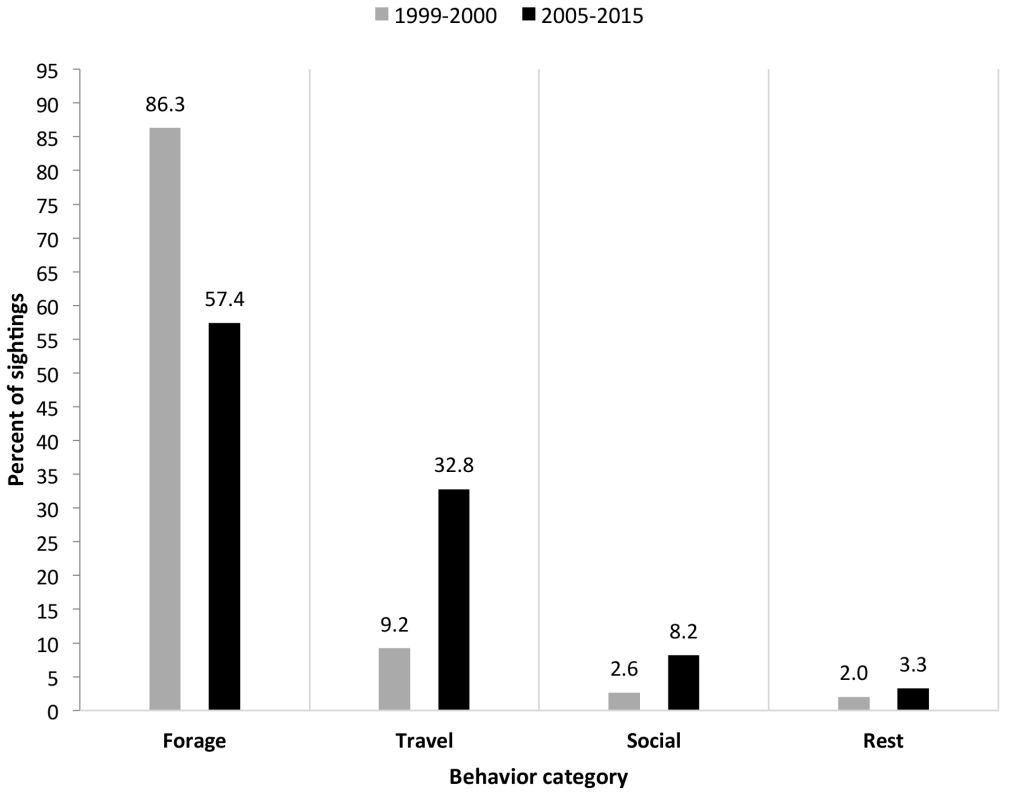

Figure 3. Percentage of sightings for each behavior for Petersen's (2001) 1999-2000 data (n = 153) and our 2005-2015 data (n = 61). Does not include sightings categorized as "Undetermined." Sightings categorized as "Combination" were included in every behavior category observed during the sighting.

Sightings Distribution

The sightings were mapped to identify distribution for all dolphins observed from 2005 to 2015 (Figure 4). Only 37 of 74 sightings were used to create the map. The majority of the mapped sightings occur on the west side of the mangrove islands, below Heusner's Bogue. However, this may be related to effort.

Summaries for the boat surveys used in this distribution map when classified as within or outside the SCWS are shown in Table 3. Overall, most of our survey time was spent outside of the SCWS. Consequently, we recorded a higher number of sightings and number of dolphin sightings outside the SCWS. There was no significant difference between the number of sightings per hour within the SCWS and the number of sightings per hour outside the SCWS ($\chi^2 = 0.000$, df = 1, $p = 0.988$).

The distribution map for only behaviorally classified sightings for the 2005-2015 surveys (n = 33) was compared with Petersen's (2001) map (n = 153) (Figure 5). Like our map, Petersen's (2001) map showed most of their sightings occurring on the mangroves' west side. However, those sightings were more disperse and not as concentrated below Heusner's Bogue. The SCWS was established after the 1999-2000 period in 2002. The creation of the SCWS does not appear to have caused a drift toward the SCWS. The percentage of sightings within the SCWS was similar between datasets: 29.0% (1999-2000) and 24.0% (2005-2015). Survey data for individual surveys are unavailable for Petersen (2001), so we were unable to retrieve the information necessary to calculate a value for the number of sightings per hour or the number of dolphins sighted per hour within vs outside SCWS for the 1999-2000 data.

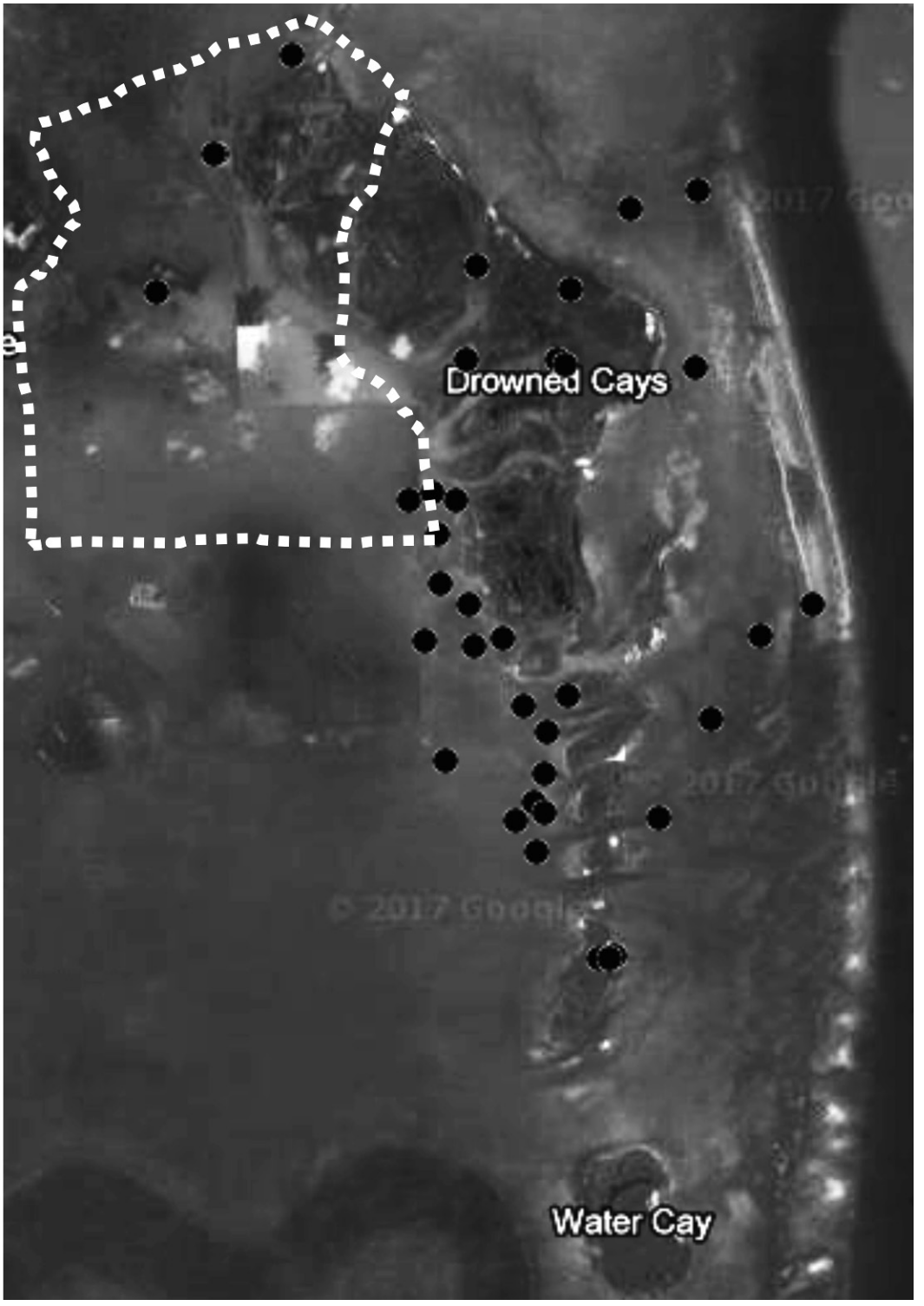

Figure 4. Distribution of observation sites for 2005-2015 surveys (*Google Maps* 2016). Each dot represents one sighting (n = 37). The white dashed outline represents the approximate location of the SCWS.

Table 3. Summaries for the boat surveys used in the 2005-2015 distribution map (n = 37) classified as within or outside the SCWS

	Within SCWS	Outside SCWS
Total survey time (hh:mm)	20.9	75.4
Number of sightings	8	29
Number of dolphins sighted	15	70
Number of sightings per hour	0.4	0.4
Average number of dolphins per sighting	1.9	2.4

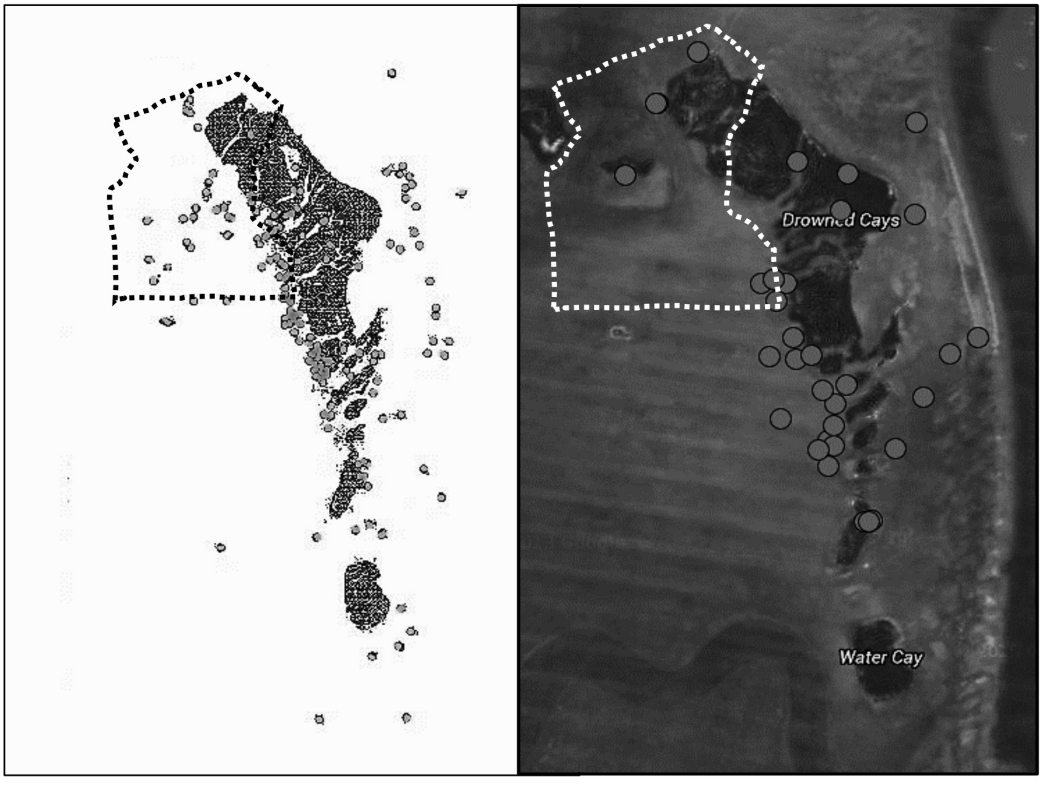

Figure 5. *Left:* Distribution of behaviorally classified encounters for 1999-2000 (n = 153; Petersen, 2001). *Right:* Distribution for 2005-2015 behaviorally classified encounters (n = 33; *Google Maps* 2016). The dashed outlines represent the approximate location of the SCWS. The number of sightings for 2005 to 2015 (n = 8) and Petersen (2001) (n = 45) are presented.

Discussion

The number of sightings occurring per hour in the Drowned Cayes did not change significantly from the 1999-2000 survey to the 2005-2015 surveys. However, the low number of sightings per hour (0.3 sightings/h) and the low proportion of survey time that dolphins were observed during 2005 to 2015 (10.8% of total survey time) could infer a small population size. In highly populated areas, sightings would occur more frequently and, therefore, observation times as a proportion of survey times would be higher. In low population areas, the observation time as a proportion of survey time would be expected to be lower since more time would be spent looking for dolphins. Our values for observation duration suggest that the current dolphin population size in the Drowned Cayes is small in comparison to other areas of Belize. For example, observation duration for dolphins in the Turneffe Atoll range was between 23 and 24% of total survey times (Campbell et al.,

2002; Hancock, 2007). In the 2005-2015 surveys, observation duration values were low compared to values from previous studies in the Drowned Cayes. Petersen (2001) observed dolphins during 17.2% of total survey time. In 1997 to 2000, dolphins were observed during 22% of total survey time (Kerr et al., 2005). However, different survey techniques could also account for lower observation times and may have negatively biased our sightings per survey. While Petersen (2001) and Kerr et al.'s (2005) data were collected during dedicated dolphin research projects, the 2005-2012 data were collected during joint dolphin–manatee research projects. Although all efforts were made to keep an eye out for animals in our surroundings during sightings, this could have resulted in missed sightings since our survey effort was split between the two species.

All 2015 surveys were dedicated specifically to dolphins, yet the observation time for that year was one of the lowest recorded from our dataset. Our scan survey technique also may have influenced our recorded observation lengths. Because we only observed the dolphin(s) for small amounts of time (only to determine behavior and group size), we were the ones to determine when the sighting ended. Had we completed focal follows, our observation times would have been longer. Our sampling technique was based on Petersen (2001) to facilitate direct comparison between time periods.

Our average number of dolphins per sighting (2.6) was small, supporting our suggestion that the Drowned Cayes dolphin population is small. This estimate is similar to those reported by Petersen (2001) and Kerr et al. (2005) (2.7 and 2.9, respectively). Kerr et al. (2005) reported the largest group observation of 20 dolphins as compared with eight dolphins as the largest group in our observations. Still, the number of dolphins per sighting appears to have stayed the same across all three studies. Although group sizes have not changed, the increased amount of time between sightings may mean that the dolphin population in the Drowned Cayes has decreased since the 1990s. It is possible that this decline is in relation to increased human activity. In 2015, cruise ships were seen on three survey days and an island hopper on another. On those days, only one 5-min sighting was observed. However, on the days that recorded zero cruise ships, nine dolphin sightings occurred lasting a total of 2 h and 55 min, accounting for 89.0% of the total observation time for 2015. This suggests that, even with the low sample sizes, the presence of cruise ships causes dolphins to appear to avoid the area.

The prevalence of mother–calf pairs observed hints that the study site could also be a nursery area. Calves made up 16.5% of the dolphins observed in 1999-2000; and in 2015, eight out of 11 surveys (72.7%) included mother–calf pairs. Kerr et al (2005) previously reported 22% of groups with calves. Nursery grounds and foraging grounds are usually located in areas with high productivity (Scott et al., 1990; Stockin et al., 2009).

Traveling is often the most common behavior to occur in higher amounts naturally (Hanson & Defran, 1993), but this behavior represented only about a third of our behavioral observations. Foraging was the most common behavior observed in our surveys. Usually, traveling occurs in combination with other behaviors and is common in the late morning and early afternoon. Although both datasets were collected during late morning and early afternoon surveys, foraging remained the main activity for more than half of all observed behaviors. Petersen's (2001) observations also showed greater foraging than other behaviors. Taken together, it is likely the Drowned Cayes in Belize are used primarily for foraging.

Although foraging was the main behavior for both datasets, the percentages changed with 28.9% more foraging documented in the earlier time period. Interestingly, there was a 23.6% increase in traveling behavior between time periods. There are two possible reasons to explain these trends. The first reason involves food availability: high study effort and low sighting rates may suggest low prey abundance. Patchiness of food resources may cause an increase in travel (Stockin et al., 2009). Perhaps now, dolphins need to travel more to get to their prey because the latter are not available in the quantities they were before. Therefore, foraging may still be the most common behavior. If food resources have become less available, dolphins would have to travel to find areas of high productivity. The second reason involves disturbance related to an increase of human activity. As previously mentioned, more dolphin observations occurred on days when there were no cruise ships within the study area. If cruise ships are related to a decrease of dolphins, then the ships might be impacting foraging success. Dolphins may begin to avoid foraging grounds due to the increase in boat traffic, and they may start traveling to other areas outside the study area. Continuing research is needed to determine if the relationship between the presence of cruise ships and dolphin sightings in the Drowned Cayes exists since long-term effects may become a problem for this small population. For example, Christiansen et al. (2013) found that whale-watching boat presence caused a decrease in foraging and surface feeding behavior of odontocete and mysticete species which could ultimately lead to long-term effects on reproductive success, population growth rates,

and individual survival. The Drowned Cayes are located within the Belize Barrier Reef Lagoon System. Not only is it an area of high productivity, but the system offers protection from predation, making it a safer habitat for dolphins. The increase in traveling, decrease in foraging, and changing presence of dolphins in general is concerning and must be examined to better understand whether human activity is the root cause.

Although the SCWS was established to reduce the tourism impact on marine habitats near Belize City, it appears that it is of minimal effect to the Drowned Cayes' manatee population (Self-Sullivan, 2007). Data showed that the probabilities of observing scarred manatees within or outside the sanctuary are the same, suggesting that there is no preference for the SCWS over the larger Drowned Cayes area. Additionally, the area was already of high use to manatees, and a decrease of animals in the area due to increased boat traffic has not been observed. Similarly, we were not able to find an increased number of sightings within or around the SCWS for our dolphin population. When compared side by side to the distribution map for 1999-2000 (Petersen, 2001), the general layout of sightings is similar. It does not look like dolphins have shifted their activity toward the sanctuary since the percentage of sightings within the SCWS is not used as had been planned. Speed limit signs and rules are posted in and around the sanctuary boundaries, but there are often no patrols to enforce the rules due to budget constraints. If boat captains do not respect the sanctuary rules, then boat impact is not reduced. Therefore, the SCWS might not be realized as the planned-for sanctuary.

In both time periods, the majority of the sightings occurred on the west side of the Drowned Cayes. While this distribution may be representative of the dolphins' behavior and habitat use, the results could also have been affected by our survey methods. We followed a similar survey route daily, almost always along the west side (leeward) of the Drowned Cayes. Still, Petersen (2001) followed the same course, so the comparisons made between the two time periods would not be affected by this bias.

Based on the data available, we conclude that the dolphin population in the Drowned Cayes may be susceptible to changes in behavior and habitat use due to increased human activity. This is of major concern since the area appears to be used predominantly as a foraging ground with consistent sighting of calves indicating a possible nursery area. Further research should be done to determine what areas within the Drowned Cayes are used for foraging and/or nurseries, and whether these areas are affected by cruise ship tourism or other human/boat activity. Additionally, it should be investigated whether the dolphin population is using the Swallow Caye Wildlife Sanctuary more frequently than nearby areas. If so, additional management strategies to address dolphin conservation should be addressed.

Acknowledgments

Data collection was permitted by the Belize Ministries of the Environment and Fisheries from 2005 to 2015 and endorsed by Coastal Zone Management. We are thankful to Sidney Turton, Spanish Bay Resort, Hugh Parkey's Belize Adventure Lodge, Hugh Parkey's Belize Dive Connection, and the Hugh Parkey Foundation for Marine Awareness and Education and their staff for hosting us over the years in Belize. We thank hundreds of visiting scientists, student interns, and Elderhostel, Oceanic Society, and Earthwatch participants who joined our field research teams from 2005 to 2015. Without this colleague, student, volunteer, and citizen support, collection of our data would have been impossible. We are grateful for everyone who donated to our project—individually, through organizations listed above, and through Experiment.com.

Literature Cited

Belize Tourism Board. (2007). *Belize tourism statistics*. Retrieved from www.belizetourism.org/belize-tourism/tourist-arrivals-by-mode-of-arrival.html

Campbell, G. S., Bilgre, B. A., & Defran, R. (2002). Bottlenose dolphins (*Tursiops truncatus*) in Turneffe Atoll, Belize: Occurrence, site fidelity, group size, and abundance. *Aquatic Mammals*, *28*(2), 170-180.

Cho, L. (2005). Marine protected areas: A tool for integrated coastal management in Belize. *Ocean & Coastal Management*, *48*(11-12), 932-947. https://doi.org/10.1016/j.ocecoaman.2005.03.007

Christiansen, F., Rasmussen, M. H., & Lusseau, D. (2013). Inferring activity budgets in wild animals to estimate the consequences of disturbances. *Behavioral Ecology*, *24*(6), 1415-1425. https://doi.org/10.1093/beheco/art086

Constantine, R. (2001). Increased avoidance of swimmers by wild bottlenose dolphins (*Tursiops truncatus*) due to long-term exposure to swim-with-dolphin tourism. *Marine Mammal Science*, *17*(4), 689-702. https://doi.org/10.1111/j.1748-7692.2001.tb01293.x

Constantine, R., Brunton, D. H., & Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation*, *117*(3), 299-307. https://doi.org/10.1016/j.biocon.2003.12.009

Duffy, R. (2000). Shadow players: Ecotourism development, corruption and state politics in Belize. *Third World*

Quarterly, *21*(3), 549-565. https://doi.org/10.1080/713701038

Ford, R. E. (1991). Toponymic generics, environment, and culture history in pre-independence Belize. *Names*, *39*(1), 1-26. https://doi.org/10.1179/nam.1991.39.1.1

Hancock, B. L. (2007). *Group characteristics, site fidelity, and social affiliation patterns of bottlenose dolphins (*Tursiops truncatus*) in Turneffe Atoll, Belize* (Master's thesis). San Diego State University, San Diego, CA. 117 pp.

Hanson, M. T., & Defran, R. (1993). The behavior and feeding ecology of the Pacific coast bottlenose dolphin, *Tursiops truncatus*. *Aquatic Mammals*, *19*(3), 127-142.

Kerr, K. A., Defran, R. H., & Campbell, G. S. (2005). Bottlenose dolphins (*Tursiops truncatus*) in the Drowned Cayes, Belize: Group size, site fidelity and abundance. *Caribbean Journal of Science*, *41*(1), 172-177.

LaCommare, K. S., Self-Sullivan, C., & Brault, S. (2008). Distribution and habitat use of Antillean manatees (*Trichechus manatus manatus*) in the Drowned Cayes area of Belize, Central America. *Aquatic Mammals*, *34*(1), 35-43. https://doi.org/10.1578/AM.34.1.2008.35

Lusseau, D., Schneider, K., Boisseau, O. J., Haase, P., Slooten, E., & Dawson, S. M. (2003). The bottlenose dolphin community of Doubtful Sound features a large proportion of long-lasting associations: Can geographic isolation explain this unique trait? *Behavioral Ecology and Sociobiology*, *54*(4), 396-405. https://doi.org/10.1007/s00265-003-0651-y

Murray, M. R., Zisman, S. A., Furley, P. A., Munro, D. M., Gibson, J., Ratter, J., . . . Place, C. J. (2003). The mangroves of Belize: Part 1. Distribution, composition and classification. *Forest Ecology and Management*, *174*(1-3), 265-279. https://doi.org/10.1016/S0378-1127(02)00036-1

Nowacek, S. M., Wells, R. S., & Solow, A. R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*, *17*(4), 673-688. https://doi.org/10.1111/j.1748-7692.2001.tb01292.x

Petersen, H. M. (2001). *Habitat use and behavior of bottlenose dolphins (*Tursiops truncatus*) in the Drowned Cayes, Belize* (Master's thesis). San Francisco State University, San Francisco, CA.

Samuels, A., & Bejder, L. (2004). Chronic interaction between humans and free-ranging bottlenose dolphins near Panama City Beach, Florida. *Journal of Cetacean Research and Management*, *6*(1), 69-77.

Scott, M. D., Wells, R. S., & Irvine, A. B. (1990). A long-term study of bottlenose dolphins on the west coast of Florida. In S. Leatherwood & R. R. Reeves (Eds.), *The bottlenose dolphin* (pp. 235-244). San Diego: Academic Press. https://doi.org/10.1016/B978-0-12-440280-5.50015-9

Self-Sullivan, C. (2007). Non-lethal boat scars on manatees in Belize as a tool for evaluation of a Marine Protected Area—Preliminary results. In *Proceedings of the Gulf and Caribbean Fisheries Institute* (pp. 535-540).

Self-Sullivan, C. (2008). *Conservation of Antillean manatees in the Drowned Cayes area of Belize* (Doctoral dissertation). Texas A&M University, College Station.

Stockin, K. A., Binedell, V., Wiseman, N., Brunton, D. H., & Orams, M. B. (2009). Behavior of free-ranging common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand. *Marine Mammal Science*, *25*(2), 283-301. https://doi.org/10.1111/j.1748-7692.2008.00262.x