Changes in Tursiops truncatus Distribution and Behavior in the Drowned Cayes, Belize, and Correlation to Human Impacts

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

by

Jazmin Garcia

Submitted to the Faculty of
Halmos College of Natural Sciences and Oceanography
in partial fulfillment of the requirements for
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Jazmin Garcia

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Abstract

Human interaction greatly influences the behavior and distribution of bottlenose dolphins (*Tursiops truncatus*). This project focuses 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 the turn of the millennium, development and ecotourism activity has flourished in the area, increasing by more than 800,000 visitors from 1998-2006. Boat-based surveys were conducted in 2015 and were combined with previous survey data collected from 2005-2012 and compared to behavioral survey results from 1999-2000. Total dolphin observation time as a percent of total survey time and average number of dolphins per sighting were 17.2% and 2.7 in 1999-2000 and 10.8% and 1.6 for 2005-2015. The low number of dolphins and the low observation times suggest that the dolphin population in the Drowned Cayes have decreased since the 1990s. Eighty-nine percent of the total observation time for 2015 occurred on days in which there were zero cruise ships in the area suggesting that this decline may be in relation to increased human activity. Furthermore, foraging was the main behavior observed for both 1999-2000 and 2005-2015 data sets, suggesting that the Drowned Cayes area is used as a foraging ground. However, in 1999-2000 the foraging percentage was significantly higher than the 2005-2015 data set, dropping 28.9% and there was a 23.6% increase in traveling behavior between the two data sets. This could be a result of increased human activity.

Additionally, survey photographs and results were used in the creation of the first dolphin photo identification database for the country. The guidelines used for photo analysis for photo quality and fin distinctiveness were tested to determine if they are easy to use and give consistent and reliable results regardless of judge. An intraclass correlation model calculated substantial agreement (ICC = 0.7) between judges’ scores, demonstrating consistent results, regardless of experience level. Therefore, the guideline can be used as a standard among multiple researchers.

Key Words: *Tursiops truncatus*, bottlenose dolphin, Drowned Cayes, Belize, ecotourism, behavior, cruise ships, conservation, photo identification, human impacts
INTRODUCTION

*Tursiops truncatus* (Cetacea: Delphinidae), commonly known as the bottlenose dolphin, is the most studied of any of the toothed cetaceans (Mattos, Dalla Rosa, and Fruet 2007). Many populations inhabit coastal areas, making them one of the most accessible cetaceans (Ingram and Rognan 2002, Mattos, Dalla Rosa, and Fruet 2007, Petersen 2001). Previous studies have documented the ecology, habitat use, and behavior of bottlenose dolphins in a variety of locations (Connor, Smolker, and Bejder 2006, Shane, Wells, and Würsig 1986, Stockin et al. 2009, Vollmer and Rosel 2013, Wursig and Wursig 1979), but populations in many areas that have not been fully investigated. It is important to continue research on bottlenose dolphins to better understand variations in behavior, which is known to occur at the population level (Campbell, Bilgre, and Defran 2002, Lusseau et al. 2006, Sargeant et al. 2007, Vollmer and Rosel 2013).

A topic relating to habitat use and behavior that needs further exploration is human impact. Cases have shown that in the presence of humans, common behaviors occur less frequently and many dolphins will actively avoid areas of high human traffic (Constantine, Brunton, and Dennis 2004, Lusseau 2003, Nowacek, Wells, and Solow 2001). However, many of these dolphin observations occur in areas that already have high human activity. Interests arise in sites that have recently become more developed and have increased tourism pressure, such as the Drowned Cayes, Belize, as dolphins may become susceptible to these effects. Determining changes in behavior can be beneficial to the dolphin population; the results give insight as to what activities by coastal communities increase changes in behaviors of bottlenose dolphins. This information is essential for stakeholders attempting to influence policy regarding conservation of marine areas, such as what terrestrial areas should be avoided when developing, as well as which water areas should be restricted by boats, and can also be used to educate local communities on their effects on bottlenose dolphins.

GOALS AND OBJECTIVES

The overall goal of my study was to repeat the bottlenose dolphin survey of 1999 by Petersen (2001) to document any change in the ecology, behavior and habitat use by the population previously identified and described.
Objectives of this study were:

- Review and expand our body of scientific knowledge related to the ecology and behavior of bottlenose dolphins in the Drowned Cayes, Belize;
- Review current guidelines for photo identification and test for consistency and reliability of methods and agreement between people rating the images, or judges;
- Repeat observational boat surveys and compare behaviors observed in this study to those observed over a decade ago by Petersen 2001 to determine changes in the population;
- Determine differences in the number of dolphins observed within or outside the Swallow Caye Wildlife Sanctuary (SCWS);
- Determine whether changes are influenced by anthropogenic activity in the habitat;
- Analyze collection of dolphin fin photos for photo quality and fin distinctiveness, in collaboration with other scientists, to develop an online photo-id database on the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) website, maintained by Duke University, for the dolphins in Belize.

HYPOTHESES

The objectives call for testing the following null hypotheses:

- There is no significant difference in the number of dolphins observe by Petersen (2001) and the number of dolphins observed in this study.
- The behaviors observed in this project are not significantly different than the behaviors observed by Petersen (2001); foraging will still be the dominant behavior.
- There is no difference in the number of dolphins observed within or outside the SCWS.
• Photo analysis ratings will be consistent between judges and ratings for photo quality and fin distinctiveness will not be different between judges, regardless of the amount of experience with photo identification.

REVIEW OF LITERATURE

**Bottlenose Dolphin Ecology**

Bottlenose dolphins inhabit temperate and tropical waters from 45° N to 45° S (Jefferson et al. 1993, Gowans, Würsig, and Karczmarski 2007). They are found in a variety of marine and estuarine habitats, and can be found near the coast or offshore, although population densities appear to be higher nearshore (Jefferson et al. 2011, Mattos, Dalla Rosa, and Fruet 2007, Petersen 2001). Site fidelity in dolphins has been observed in various degrees at different locations and patterns of occurrence have been associated with season, tidal state, and time of day (Petersen 2001).

The gestation period for bottlenose dolphins is about 1 year. Births occur in all seasons, but peak during spring and summer months, as warm water is thermally efficient for small calves and mothers (Mann et al. 2000, Perrin, Wursig, and Thewissen 2009). Calves are born measuring 84 to 140 cm. Mothers will stay with their calves for 3 to 6 years and separation often coincides with the birth of the next calf (Perrin, Wursig, and Thewissen 2009). Female common bottlenose dolphins can live more than 57 years, whereas males live up to 48.

The diet of bottlenose dolphins varies by region and is dependent on local prey availability (Ridgway and Harrison 1999). They are opportunistic feeders; feeding on a variety of fish, some cephalopods, shrimp, and small rays and sharks. Differences were found between the stomach contents of coastal and offshore dolphins in North Carolina, indicating that there are diet differences based on habitat (Gannon and Waples 2004). Both coastal and offshore dolphins shared a variety of prey items, but offshore dolphins had more equally distributed amounts of prey whereas coastal dolphins relied mostly on one prey item. Offshore dolphins’ diet was primarily composed of weakfish; coastal dolphins’ diet was primarily composed of croaker and spot. Additionally, although prey
species overlapped, offshore dolphins’ stomach contents contained larger fish, whereas coastal dolphins contained more prey items overall (Gannon and Waples 2004).

Bottlenose live in fission/fusion groupings, where group size and members change frequently depending on the activity (Gowans, Würsig, and Karczmarski 2007). They are usually found in groups of up to 15, but herds over 100 are often seen offshore (Ridgway and Harrison 1999, Jefferson et al. 1993). Generally, dolphins in bays and estuaries form smaller groups than those offshore (Ridgway and Harrison 1999). Differences in group size between inshore and offshore groups may due to foraging techniques. Inshore, food is evenly distributed, whereas offshore food sources are spread out. Therefore, more dolphins may increase the probability of finding the food source. Other benefits of group living are reduced predation, enhanced reproduction, and the possibility of social interaction and learning (Gowans, Würsig, and Karczmarski 2007).

**Bottlenose Dolphin Behavior**

Bottlenose dolphin behavior is described in terms of four major categories – feeding, traveling, social interactions, and resting (Shane, Wells, and Würsig 1986):

*Feeding*

Feeding behavior is diverse and includes both social and solitary behaviors. It is described as any effort to pursue, capture, and/or consume prey (Stockin et al. 2009). Dolphins have been observed circling around schools of fish, herding them to the surface while one or two individuals dart into the school to feed, diving into the sand to catch prey, jumping out of the water to grab their prey in the air, and stranding themselves and prey on mudbanks (Gowans, Würsig, and Karczmarski 2007, Mann 2000). Others have been seen following trawling shrimp boats to feed, feeding on fish discarded by fishermen, and feeding around anchor shrimp boats (Shane, Wells, and Würsig 1986). More time is spent feeding during the early morning and late afternoon and also occurs higher during high tide than low tide (Hanson and Defran 1993).
**Traveling**

Dolphins in various populations appear to spend most of their time traveling. Traveling occurs in the late morning and early afternoon. However, traveling is usually not observed as an independent activity, instead, it is observed in part with other behaviors (Hanson and Defran 1993).

**Social Interaction**

Social interactions are also diverse. Bottlenose dolphins use proximity, physical contact and synchronicity to express affiliation. Strongly bonded males will swim side by side and surface at the same time; mothers and calves will swim in close proximity and synchronously. Contact swimming, as well as other touching behaviors including gentle stroking with the pectoral fin, rubbing, and petting, have been observed. Other behaviors include slapping of body parts, such as the flukes, on the water surface; “rooster struts”, in which 2 or 3 males simultaneously bob their heads above the surface; and “butterfly” displays, in which males will swim in figure eights around the female forming “wings”. The purpose or reasons for these behaviors are not clear (Mann 2000).

**Resting**

Resting behavior is associated with slow movements and lack of the other major behaviors (Shane, Wells, and Würsig 1986). Dolphins are observed in tight groups and demonstrate slow, often predictable surfacing behavior (Stockin et al. 2009).

**Anthropogenic Effects on Behavior**

A growing industry in coastal areas is ecotourism. Its gain of popularity coincides with the increasing sentiment of wanting to experience focal animals in the wild, rather than in captive settings (Higham et al. 2016). Swim-with-dolphin programs began in 1985 and allow the public to enter a pool with captive dolphins for recreational swimming. It has become a “must do’ activity for many tourists due to dolphins’ charismatic appeal and the belief that dolphins are non-aggressive animals (Samuels and Spradlin 1995). Cetacean-watching tourism has increased; from 1991 to 1998, the number of tourists involved in such activities increased by 5 million (Hoyt 2001).
Potential benefits of ecotourism include the environmental awareness and generating revenue for the local communities (Amante-Helweg 1996, Constantine, Brunton, and Dennis 2004). It is pushed as an ideal development strategy combining economic growth with environmental conservation (Duffy 2000). For instance, within the last decade, marine tourism has generated more global revenue than aquaculture and fisheries combined (Higham et al. 2016). Although ecotourism is beneficial in some aspects, it also has some downfalls. Swim-with-dolphin programs have been shown to be risky for human participants, as dolphins may show aggressive or sexual behavior in some encounters, and also for the dolphins themselves under certain conditions (Samuels and Spradlin 1995). Cetacean-watching tourism is mostly boat based, leading to an increase in boat traffic around the animal and a higher risk of boat collisions (Lusseau 2003). Other indirect effects are still not understood (Hoyt 2001, Lusseau 2003). Potential negative impacts on the species include interruption on their feeding, mating, and calving cycles and separation of calves from their mothers.

Previous studies indicate that ecotourism causes increased risks and changes in the behavior of bottlenose dolphins. A study on the effects of swim-with-dolphins’ activities in Panama Beach, Florida found that human interaction was harmful to the population of bottlenose dolphins. It appeared that feeding was the basis for encounters with dolphins, causing dolphins to approach any vessel or swimmer. Uncontrolled feeding of dolphins occurred at high rates, making the dolphins vulnerable to injury, illness, or death (Samuels and Bejder 2004). Juvenile dolphins have been found to be the most likely to interact with swimmers, as they may use these interactions as part of their development through play (Constantine 2001). However, feeding of juveniles could also interfere with the development of foraging and social skills needed for survival (Samuels and Bejder 2004).

Bottlenose dolphins in the Bay of Islands, New Zealand showed increase avoidance of swimmers, which could cause long-term effects such as displacing foraging, resting, or socializing at these locations (Constantine 2001). They also demonstrated a change in behavior in the presence of dolphin-watching tour boats. Dolphin behavior was affected by the number of boats present and boat type; resting decreased significantly
with increasing number of boats. This is of major concern since resting is fundamentally important to the health of many animals and could cause physiological stress if reduced (Constantine, Brunton, and Dennis 2004). Dolphins have been observed increasing their speed and altering their course to move away from approaching boats (Nowacek, Wells, and Solow 2001). Boat interactions also influence the diving pattern of bottlenose dolphins. Dolphins display vertical avoidance, in which they will increase their dive intervals when boats were approaching (Lusseau 2003). They use acoustic cues to determine the distance of the approaching boat and plan their dives based on that information (Nowacek, Wells, and Solow 2001).

Management, planning, and continued research on the effect of ecotourism on dolphins is needed to make ecotourism sustainable and not harmful to the animals involved (Garrod and Wilson 2004).

**Photo Identification**

Since the discovery that individuals of many cetacean species have distinctive natural variations in appearance visible in photography, free-ranging cetacean research has increased in both quantity and quality (Blackmer, Anderson, and Weinrich 2000, Hammond, Mizroch, and Donovan 1990). Photo identification pioneered in the early 1970s and was used for studies concentrated on distribution, migration, behavior, and general life history. However, it was soon evident that it could also be used to estimate cetacean population parameters, such as abundance, reproductive rates, and population differentiation, all which are important for conservation management (Wursig and Jefferson 1990).

Among whales, individual variation occurs on the flanks of blue whales, dorsal fin shapes of fin, sei, and minke whales, peduncles of bowhead whales, and flukes and dorsal fin shapes of humpback whales (Blackmer, Anderson, and Weinrich 2000, Hammond, Mizroch, and Donovan 1990). In bottlenose dolphins, individual variation occurs on their dorsal fins, predominantly their shape and scarring. Photo-identification assumes that there is little change in the appearance of the features used for identification for adults; features of calf fins would change as they grow (Blackmer, Anderson, and Weinrich 2000, Hammond, Mizroch, and Donovan 1990).
The biggest problems associated with using natural markings to identify individuals are the degree of distinctiveness of the individual’s marks and the quality of the photograph being used. Marks on some individuals could be easier to distinguish than others and this could cause misrepresentation of those individuals with less distinct marks (Friday et al. 2000). Digital photography allows thousands of photos to be taken, but those photos must be analyzed for quality in a consistent manner (Rosel et al. 2011). Low-quality photographs could make it difficult to recognize features on fins. This could cause inconsistencies in abundance calculations as individuals with more distinctive features could be readily recognized in photos of varying quality, but less distinctive individuals would only be recognized in high-quality photographs (Friday et al. 2000). Obtaining high-quality images of dorsal fins is essential to obtain unbiased results (Rosel et al. 2011). Systems for grading image quality and fin distinctiveness have been used but need improvement. They need to be agreed upon and implemented for uniformity throughout the field.

METHODS

Study Area

The Drowned Cayes is a chain of mangrove islands within the Belize Barrier Reef Lagoon System (Fig 1) (LaCommare, Self-Sullivan, and Brault 2008, Petersen 2001). This 15 km long mangrove chain lies approximately 5 km east of Belize City and 3 km west of the reef. The Drowned Cayes are a complex area of high productivity, characterized by seagrass beds, mangrove islands, and patch reefs. Most of the Drowned Cayes are uninhabitable due to the lack of dry land, however, over a half dozen sites have been dredged and filled for development, including fish camps and small resorts (Self-Sullivan, personal communication).

Belize falls between subtropical and tropical conditions. The dry season runs from December to April and the wet season runs May to November. Along the coast, the maximum temperature reached is 31˚C in July and the lowest is 19˚C in January (Murray et al. 2003).
The study area covers approximately 200 square kilometers. Water depth is shallow, with a maximum depth of 5 meters, except for the eastern channel which reaches up to 50 meters. Channels, referred to as bogues, run into and between the cayes. Little tidal variation exists; the tidal range is less than 0.3 m (LaCommare, Self-Sullivan, and Brault 2008, Petersen 2001).

Figure 1. Map of Belize City and Drowned Cayes study area (Google Maps 2016)

Prior to the 2000s, the area surrounding the Drowned Cayes was relatively undisturbed and human activity was minimal (Petersen 2001). Tourist facilities expanded in the 1980s, and since the turn of the millennium, development and ecotourism have increased exponentially (Duffy 2000, Self-Sullivan 2008). From 1998 to 2006, there was an increase of over 800,000 visitors entering Belize via cruise ships, and cruise ship tourism increased 692% between 2001 and 2004 (Board 2007, Self-Sullivan 2007). By the year 2000, tourism was Belize’s largest foreign exchange earner, and principal areas such as Caye Caulker and San Pedro switched from dependence on fishing to a tourism economy (Duffy 2000). This causes concern as this increase in tourism may deleteriously
impact marine mammal habitats (LaCommare, Self-Sullivan, and Brault 2008). Much of the activity that occurs within the Belize Barrier Reef Lagoon System is human generated, particularly boat traffic from tourism, small-scale fishing near Belize City, and commercial fisheries that get conch and lobster from the reef (Cho 2005, Petersen 2001). The close proximity of Belize City and the Belize River to the Drown Cayes places increased pressure on levels of resource extraction, pollution, and boat traffic in this region (Kerr, DeFran, and Campbell 2005).

Figure 2. Swallow Caye Wildlife Sanctuary (SCWS) (Friends of Swallow Caye 2016b)

The two most northern mangrove islands within the Drowned Cayes are included in the Swallow Caye Wildlife Sanctuary (SCWS) (Fig 2). The SCWS was established in July 2002 after local manatee tour operators pushed for a Marine Protected Areas, in an effort to mediate impact on marine habitats near Belize City. The sanctuary encompasses 8,970 acres of sea grass beds, deeper channels, and mangrove islands (Self-Sullivan 2008). The boundary for SCWS was selected based on local knowledge, opportunism,
emphasis on socio-economic-political concerns, and little scientific input (Self-Sullivan 2007). Most rules and regulations are directed to manatee tour operators, such as limited access near manatee resting holes. Some rules, however, are directed towards all boats passing through the sanctuary – boats must enter and exit the sanctuary through the designated point; signs throughout the sanctuary tell the boat operators when to reduce speed or to turn off their engines and pole their way through; noise pollution, including loud music, and littering is banned (Friends of Swallow Caye 2016a).

Bottlenose dolphins have been studied in Belize since 1992 (Petersen 2001). Turneffe Atoll studies have found small group sizes, and although being located just 16 km east of the Drowned Cayes, no overlap between the dolphin populations had been documented until 2007, when three photographic matches of individuals and one possible identification have been made between the two sites (Hancock 2007, Kerr, Defran, and Campbell 2005). Surveys conducted during 1997-1999 in the Drowned Cayes sighted 2155 dolphins, with a mean group size of 2.9, one of the smallest reported for bottlenose dolphins. However, only 30% of identified were classified as residents, indicating that the dolphin population in the Drowned Cayes is both small and finite (Kerr, Defran, and Campbell 2005). Petersen (2001) completed the last study to date on the bottlenose dolphin population, and her dataset was used to compare changes in behavior and habitat use. Petersen studied habitat use and behavior of bottlenose dolphin in the Drowned Cayes during 1999-2000. A total of 149 surveys were conducted. A total of 169 sightings were made, with 455 dolphins sighted overall. Petersen found that most of the study area is used for foraging, accounting for 86.3% of the sightings for which behavioral assessments were possible (Petersen 2001). The majority of the dolphin sightings occurred in the mangrove channels, referred to as bogues (Ford 1991). There were also high occurrences of foraging behavior combined with either travel or social interactions. Not enough information was collected to determine if the dolphins show site fidelity. Additionally, a high number of calves were recorded, suggesting that the area is used as a nursery (Petersen 2001).
Data Collection

A two-week survey was conducted August 10-23, 2015. Surveys were conducted on both east and west sides of the mangrove islands as well as through the bogues, Swallow Caye, Stimpy’s Lagoon and Gallows Reef (Fig 3). Both coasts and all bogues were surveyed at least once during the two-week period, sights were repeated opportunistically thereafter. Surveys were conducted by the author, field advisor, three students, and the local boat captain. Surveys occurred in the morning and early afternoon between 8am and 4pm. 28- and 30-foot skiffs equipped with 175 horsepower outboard engines were used for the surveys and an average speed of 8.5 km/hour was maintained throughout the surveys.

For each survey, the date; area or bogue name; beginning and ending positions (GPS coordinates) and times; sea state; cloud coverage; swell height; and the amount of precipitation were recorded. Bogues were labeled as inside or outside the Swallow Caye Wildlife Sanctuary (SCWS). Sea state was determined using the Beaufort scale:

0 – sea like a mirror
1 – scale-like ripples with no foam crests
2 – small wavelets with glassy appearance but not breaking
3 – large wavelets with crests beginning to break and scattered whitecaps
4 – large wavelets 0.5-1.25 meters high and numerous whitecaps

Bogues were surveyed by traveling slowly from one end to the other. Once a dolphin was sighted, we approached slowly 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 be considered focal follows, which focuses on each individual for a same predetermined time (Altmann 1974).
Figure 3. Drowned Caves study site with locations and bogues identified. Created in ArcGIS by Marie-Lys Bacchus, labels added by Jazmin Garcia. Sites with an asterisk (*) are located within the SCWS. (Self-Sullivan et al 2008)
To document the quality of sighting conditions, the Beaufort sea state, cloud coverage, swell height and amount of precipitation were documented during each dolphin sighting. The date, beginning and ending time of observation, GPS position, group size, number of calves, number of cruise ships, and other comments were recorded for each sighting. Behavioral state of the dolphins was categorized as forage, rest, social, travel, or a combination of these. Petersen (2001) described each behavior as follows:

**Forage:** The most variable behavioral state. Usually recognized by long, peduncle out or fluke out dives, occurring in varying directions in a generally localized manner. Includes observations of fish capture and ingestion, and indirect indications of foraging. Foraging dolphins might swim parallel to mangrove shores and perform tail-slaps, rushes, and turns, creating splashes. Occasionally fish may be seen leaping out of the water. Foraging dolphins might explore seagrass beds, nodding their heads and vocalizing or investigating fish traps, rolling traps over and vocalizing. Seabirds may be associated with foraging dolphins, but will not be considered as indicators of dolphin location or behavior.

**Rest:** Characterized by relatively motionless drifting or slight movement of pumping the flukes. The dolphin will be observed slowly surfacing to breathe and then sinking slowly below the surface.

**Social:** High level of activity between two or more individuals, usually occurring at or near the surface, creating a lot of splashing. Easily recognizable, but difficult to view clearly. Dolphins may maintain close contacts, frequently rubbing their bodies together. Various body parts, such as flippers, flukes, heads, and sides might be exposed about the water surface. Includes leaps.

**Travel:** Direction and speed may vary, but travel will be recognized as directional movement of the individual or the group as a whole, with all dolphins maintaining a similar bearing.

Once the data were recorded, a new survey was started from the ending point of the previous sighting.
Data Analysis

Data from the 2015 surveys were combined with previous data collected from 2005 to 2012. The data for those years come from opportunistic dolphin encounters while the field advisor, Dr. Caryn Self-Sullivan, and her team were in the study area completing manatee surveys. With the exception of half a dozen sightings, most dolphin encounters occurred without the presence of manatees (Knowles 2015). Start and end times of sightings, GPS locations, group size, and behavioral state we documented for each encounter and the survey data for the manatee surveys were used as the overall survey times and effort associated with the encounter. For dolphin sightings which were opportunistic (n=10) – i.e. encountered during a time when the team was not completing a boat survey, either on the way back to the resort or from the resort’s dock – overall survey times were the same as encounter times. For example, if an opportunistic encounter lasted 10 minutes, the total survey time was also 10 minutes.

All the data were entered into an excel spreadsheet. The excel spreadsheet included the year, survey number, survey start and end time, survey length (hours:minutes), as well as encounter number, encounter start and end time, encounter length (hh:mm), group size, behavior, and the latitude and longitude of when the dolphin(s) was first sighted. In the event that more than one encounter occurred in a survey, the survey information was only entered once, as to avoid duplicates of survey durations. Behaviors were categorized as one of the four behaviors, a combination of behaviors, or undetermined. For encounters which included an exact time during the encounter in which a behavior changed, the encounter was split up to distinguish the different durations of each behavior. For example, if an encounter lasted 15 in total, but at the 7:15 mark the behavior observed switched from foraging to travel, then the encounter was split into two encounters, a and b. Encounter a would have a duration of 7:15 and categorized as foraging behavior, and encounter b would have a duration of 6:45 and categorized as traveling behavior. Encounters in which more than one behavior was mentioned but did not show an exact time in which the behavior changed, were not altered and were categorized as combination. Those encounters where dolphins were lost before behaviors could be determined or whose data sheets did not mention any behavior
whatsoever, were categorized as undetermined. Survey lengths, encounter lengths, and group size for all surveys and encounters were added together to calculate total survey length, total encounter length, and total number of dolphins sighted, respectively. Hours spent on water equaled total survey length and the number of encounters corresponded with the total number of sightings.

Total observation time was calculated as a percentage of total survey time for the entire data set and for each year, and to determine activity budgets total time for each behavior was calculated as a percentage of total observation time. To determine whether one year differed significantly from the others in terms activity budgets, a Fisher’s Exact test was performed, which uses the proportions between groups to calculate the significance of a difference (Routledge 2005). For my data, the test compared each proportion of a behavior between years to see if there were significant differences. A p-value less than 0.050 would indicate significant differences between the activity budgets for every year.

**Comparison of 2005-2015 data vs. Petersen (2001)**

Number of hours spent on the water, number of hours spent observing dolphins, number of encounters (referred to as sightings by Petersen), and number of dolphins sighted were calculated and compared to the values given in Petersen (2001). To calculate survey effort, the total number of sightings were divided by the total number of hours spent on water. A chi-square test was completed to determine if survey efforts between the two data sets were significantly different ($\alpha = 0.05$). The chi-square test determines whether the two values occur independently of each other; p-value less than 0.050 means that the two values are significantly different. To calculate the frequency of dolphins sighted, the number of dolphins sighted was divided by the total number of hours spent on the water. A chi-square test was completed to determine if the frequencies of dolphins sighted were significantly different between data sets ($\alpha = 0.05$).

Dolphin sightings in which behavior was categorized as undetermined were removed from the set and only sightings in which behavioral assessments were possible were used for the remaining comparisons. The sightings were separated by behavioral group – forage or combination, rest or combination, social or combination, or travel or
combination. Those 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 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 calculations and a chi-square test was performed for each behavior to determine if our results were significantly different than Petersen’s results ($\alpha = 0.05$).

**Sightings Distribution**

Sighting distribution maps were created to show the sighting locations for the 2005-2015 data set. Four maps were created: 2005-2015 encounters, 2005-2015 encounters by year, 2005-2015 encounters by behavior, and 2005-2015 behaviorally-classified encounters. The maps were created using Google Maps and by entering the latitude and longitude collected either at the beginning of a dolphin encounter or at the end of the encounter, whichever was available. In the event that both coordinates were available for the sighting, the coordinates collected at the beginning of the sighting were used. Sightings that did not have latitude and longitude points available were omitted from the maps. The 2005-2015 behaviorally-classified encounters included only sightings for which behavior assessments were possible (i.e. not categorized as undetermined) in order to compare with Petersen’s distribution map. Petersen’s map was modified to improve clarity—blur lines were removed and dots that marked a sighting location were highlighted for better viewing. All attempts were made to ensure that information was not lost.

All of the maps include shaded areas to mark the location of the Swallow Caye Wildlife Sanctuary. The shaded area is only an approximation of the area. The number of sightings to fall within the shaded area in the 2005-2015 encounters map was compared to the number of sightings outside the shaded area, and a chi-square test was performed to determine significant difference ($\alpha = 0.05$). Sightings that fell between the boundary lines were counted as part of the SCWS. Additionally, for both behaviorally-classified encounter maps, the number of sightings to fall within the shaded area were counted and
compared to each other. A chi-square test was performed to determine significant difference between maps ($\alpha = 0.05$).

**Photo Analysis for Identification**

Dolphins were photographed for photo identification using a Canon digital camera with a 50-400 mm lens. These photos, along with photos collected from 2005 to 2012 were analyzed and uploaded to an OBIS-SEAMAP database for dolphins in Belize, in collaboration with Eric A. Ramos of City University of New York and other scientists.

All photographs from the collection were considered for photo analysis. Photographs were processed for image quality and fin distinctiveness using the guidelines for measurements of these parameters established by Kim Urian (Rosel et al. 2011, Urian, Hohn, and Hansen 1999, Urian et al. 2014):

Image quality was graded on 5 characteristics: image focus/clarity, degree of contrast between the fin and background, the angle of the fin to the plane of the photograph, the amount of dorsal fin visible, and the proportion of the frame that is filled by the fin. Each characteristic was given an individual score and they were added together to get the overall photographic quality or Overall Score.

- **Focus/clarity**: 2 = excellent focus, 4 = moderate focus, 9 = poor focus, very blurry
- **Contrast**: 1 = ideal contrast, 3 = either excessive contrast or minimal contrast
- **Angle**: 1 = perpendicular to camera, 2 = slight angle, 8 = oblique angle
- **Fin visibility**: 1 = the fin is fully visible, leading and trailing edge, 8 = the fin is partially obscured
- **Proportion**: based on the percentage area the fin occupies relative to the total area of the frame
  - 1 = greater than 5%; subtle features are visible
  - 5 = less than 1%; fin is very distant
Overall Photographic Quality: sum the scores for each characteristic

6 – 9: Excellent quality ➔ Q-1

10 – 12: Average quality ➔ Q-2

> 12: Poor Quality ➔ Q-3

Image distinctiveness was graded as D-1, D-2, or D-3 and was based on the amount of information on the fin: leading and trailing edge features, pattern, marks, and scars.

D-1: very distinctive, features evident even in distant or poor quality photograph

D-2: average amount of information content; 2 features or 1 major feature are visible on the fin.

D-3: not distinctive; very little information content in pattern, markings or leading and trailing edge features

Image scoring for image quality and fin distinctiveness occurred independently of each other (Rosel et al. 2011). Photographs that meet the Q1 and D-1 or D-2 criteria have been extracted, matched, and identified as individual dolphins. The best left and right side images of each dolphin will be uploaded to the OBIS-SEAMAP database in conjunction with those images of Turneffe Atoll and Port of Honduras Marine Reserve’s dolphin populations.

To reduce a number of photographs analyzed, each photograph was reviewed by the author. Images in which only half the dorsal fin was visible or the fin was at an oblique angle were eliminated before photo analysis occurred. However, all images have been archived to access for future work. In the event that two or more fins were present in the photographs, each fin was analyzed separately and labeled as Fin 1, Fin 2, etc., with Fin 1 being the leftmost fin in the image and so forth. All photos were cropped so that only the dorsal fin to be reviewed was visible. In order to make proportion characteristic easier to score, a “rule of thumb” trick was recommended: Use thumb to determine Proportion. If the fin is covered by thumb, the score is 5. If the fin is not covered by thumb (both width and height), the score is 1. All photos were analyzed by up to five
reviewers or judges. Judges received a copy of the original photo, to be used for the proportion of frame filled characteristic, and a copy of the cropped photo, to be used for the remaining characteristics. If rating differences occurred between judges, the difference was discussed between judges and a final rating was determined.

**Testing of Criteria for Photo Analysis and Judges’ Agreement**

To ensure that the measurement parameters for photo quality and fin distinctiveness provide consistent and reliable results and can produce similar ratings between judges, parameters were evaluated using methods similar to Friday et al (2000). Sixty images of dorsal fins were selected and given to a total of ten judges. The judges were selected based on experience: 5 of the judges had over a year of experience with photo identification, from now on referred to experts, the remaining 5 judges had limited or no experience with photo identification, and will now be referred to as novice. All of the judges were given the folder of the images, as well as a PowerPoint presentation (see Appendix A) providing Rosel et al’s (2011) guidelines for photo analysis. The presentation was created by Eric A. Ramos and edited by the author. The presentation includes and explanation of the scoring for each parameter including examples for each. An Excel sheet template (see Appendix B) was created for the judges to input their results. Additionally, a survey (see Appendix C) was given asking each judge about the ease of use of the guidelines and if they had any recommendations on how to improve the rating system.

Once all the ratings were gathered, an analysis of variance (ANOVA) was used to compare the amount of variation between groups (experts or novice) to the amount of variation within groups. An F-ratio greater than one and a p-value less than 0.050 would mean that the variation between groups is greater than the variation within groups. Additionally, agreement among individual judges was measured for each variable (Focus/Clarity, Contrast, Angel, Partial, Proportion, Overall Photographic Quality, and Overall Distinctiveness) using an intraclass correlation (ICC) model. The ICC value measured how strongly the judges’ scores agree with each other, and therefore how reliable the guidelines are to produce similar scores, regardless of experience level.
Agreement statistics have a maximum of 1, and the following divisions were used to interpret the ICC value (Landis and Koch 1977):

- < 0.00: poor agreement
- 0.00 – 0.20: slight agreement
- 0.21 – 0.40: fair agreement
- 0.41 – 0.60: moderate agreement
- 0.61 – 0.80: substantial agreement
- 0.81 – 1.00: almost perfect agreement

Furthermore, to determine if there are significant differences in rating styles, zooming in or cropping the photo, five judges were asked to rate 32 photos twice, once by zooming into the fin and another by using the cropped version of the photo provided by the author. All characteristics were rated twice, except for Proportion of Frame Filled, since only the original frame is used for this category. A series of paired t-test were performed for each judge, zoomed in vs. cropped photo, for each characteristic (Focus/Clarity, Contrast, Angle, Partial, Overall Score, and Overall Distinctiveness), with \( \alpha = 0.05 \). A p-value of 0.050 or less would mean that there are significant differences between rating by zooming in and using a cropped photo.

RESULTS

Survey Summary

A total of ten surveys were conducted from August 10-23, for a total of 51.6 hours on the water. Eleven dolphin sightings were recorded for a total of 3.3 hours spent observing dolphins, which accounts for 6.4% of total survey time. Thirteen dolphins were observed in all. The mean number of dolphins per sighting was 1.6. No groups of more than two dolphins were observed in the surveys. Four, possibly five, sightings involved mother-calf pairs, the other sightings involved just one dolphin. Beaufort Sea State ranged between 0.5 and 3.5, with a mean state of 2.6. Swell height ranged from 0 to 1 meters, with a mean height of 0.6 m. Cruise ships were recorded on three survey days, an
island hopper was spotted on another, and on four days zero cruise ships were observed (Table 1). For two days, cruise ship activity was not recorded at all.

Table 1. Summary of surveys completed in 2015

<table>
<thead>
<tr>
<th>Survey Date</th>
<th>Survey lengths (hh:mm)</th>
<th>Number of Encounters</th>
<th>Encounter Lengths (hh:mm)</th>
<th>Number of Cruise Ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-Aug-15</td>
<td>4:19</td>
<td>0</td>
<td>0:00</td>
<td>1</td>
</tr>
<tr>
<td>12-Aug-15</td>
<td>4:29</td>
<td>1</td>
<td>0:17</td>
<td>NA</td>
</tr>
<tr>
<td>13-Aug-15</td>
<td>7:00</td>
<td>1</td>
<td>0:05</td>
<td>1</td>
</tr>
<tr>
<td>15-Aug-15</td>
<td>5:47</td>
<td>2</td>
<td>0:48</td>
<td>0</td>
</tr>
<tr>
<td>16-Aug-15</td>
<td>4:11</td>
<td>0</td>
<td>0:00</td>
<td>NA</td>
</tr>
<tr>
<td>17-Aug-15</td>
<td>4:08</td>
<td>4</td>
<td>1:23</td>
<td>0</td>
</tr>
<tr>
<td>19-Aug-15</td>
<td>4:57</td>
<td>0</td>
<td>0:00</td>
<td>2</td>
</tr>
<tr>
<td>20-Aug-15</td>
<td>5:26</td>
<td>0</td>
<td>0:00</td>
<td>0*</td>
</tr>
<tr>
<td>21-Aug-15</td>
<td>6:12</td>
<td>3</td>
<td>0:44</td>
<td>0</td>
</tr>
<tr>
<td>22-Aug-15</td>
<td>5:06</td>
<td>0</td>
<td>0:00</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>51:35</td>
<td>11</td>
<td>3:17</td>
<td>4</td>
</tr>
</tbody>
</table>

* Zero cruise ships were recorded, but island hopper was observed

Table 2. Survey summaries for years 2005-2015

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Observation Time (hh:mm)</th>
<th>Total Survey Time (hh:mm)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>0:46</td>
<td>2:31</td>
<td>30.5</td>
</tr>
<tr>
<td>2006</td>
<td>8:07</td>
<td>98:46</td>
<td>8.2</td>
</tr>
<tr>
<td>2007</td>
<td>5:23</td>
<td>53:34</td>
<td>10.1</td>
</tr>
<tr>
<td>2009</td>
<td>2:17</td>
<td>5:38</td>
<td>40.5</td>
</tr>
<tr>
<td>2010</td>
<td>1:59</td>
<td>4:11</td>
<td>47.4</td>
</tr>
<tr>
<td>2011</td>
<td>1:18</td>
<td>7:15</td>
<td>17.9</td>
</tr>
<tr>
<td>2012</td>
<td>1:40</td>
<td>5:23</td>
<td>31.0</td>
</tr>
<tr>
<td>2015</td>
<td>3:17</td>
<td>51:35</td>
<td>6.4</td>
</tr>
</tbody>
</table>

When combined with previous data collected from 2005 to 2012, there was a total of 85 surveys completed. A total of 228.9 hours were spent on the water, with a total of 74 dolphin sightings, and 24.8 hours observing dolphins, accounting 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 in Table 2. A total of 192 dolphins were observed.

The mean number of dolphins per sighting was 2.6, with a range of 1 to 8 dolphins per sighting. Of the 74 sightings, 34 sightings were categorized as forage, 2 as rest, 4 as social, 19 as travel, 2 as a combination, and 13 as undetermined (Fig 4). One sighting was categorized as milling behavior, but in order to keep with the predetermined categories, it was added in the undetermined category. Total time each behavior was observed was calculated as a percentage of total observation time and summarized in Table 3. The activity budgets, or observation times of each behavior as a percentage of total observation time, are shown as a composite for all years in Figure 5, and by year in Figure 6. The Fisher’s Exact Test showed that each year differed significantly from one another in terms of activity budgets (all p values were 0.000). No one year was similar to another.

Figure 4. Total number of sightings for 2005-2015 data (n=74) by behavior type
Table 3. Total time each behavior category was observed as a percentage of total observation time

<table>
<thead>
<tr>
<th>Year</th>
<th>Forage</th>
<th>Travel</th>
<th>Social</th>
<th>Rest</th>
<th>Combination</th>
<th>Undetermined</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>67.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>32.6</td>
</tr>
<tr>
<td>2006</td>
<td>63.0</td>
<td>6.4</td>
<td>24.2</td>
<td>0.0</td>
<td>0.0</td>
<td>6.4</td>
</tr>
<tr>
<td>2007</td>
<td>38.7</td>
<td>36.5</td>
<td>0.0</td>
<td>5.0</td>
<td>0.0</td>
<td>18.9</td>
</tr>
<tr>
<td>2009</td>
<td>38.0</td>
<td>62.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>18.9</td>
</tr>
<tr>
<td>2010</td>
<td>27.7</td>
<td>5.9</td>
<td>0.0</td>
<td>0.0</td>
<td>66.4</td>
<td>0.0</td>
</tr>
<tr>
<td>2011</td>
<td>74.4</td>
<td>6.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>19.2</td>
</tr>
<tr>
<td>2012</td>
<td>33.0</td>
<td>7.0</td>
<td>0.0</td>
<td>22.0</td>
<td>38.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2015</td>
<td>52.8</td>
<td>42.6</td>
<td>2.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>50.0</td>
<td>22.7</td>
<td>8.2</td>
<td>2.6</td>
<td>7.9</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Figure 5. Composite of dolphin activity budgets for 2005-2015
Figure 6. Dolphin activity budgets for a) 2005, b) 2006, c) 2007, d) 2009, e) 2010, f) 2011, g) 2012, and h) 2015.
c)

2007

<table>
<thead>
<tr>
<th>Percent</th>
<th>Forage</th>
<th>Travel</th>
<th>Social</th>
<th>Rest</th>
<th>Combination</th>
<th>Undetermined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40.00</td>
<td>30.00</td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2009

<table>
<thead>
<tr>
<th>Percent</th>
<th>Forage</th>
<th>Travel</th>
<th>Social</th>
<th>Rest</th>
<th>Combination</th>
<th>Undetermined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40.00</td>
<td>60.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
g) 2012

- Forage: 30.00%
- Travel: 10.00%
- Social: 20.00%
- Rest: 20.00%
- Combination: 40.00%
- Undetermined: 0.00%

h) 2015

- Forage: 50.00%
- Travel: 40.00%
- Social: 10.00%
- Rest: 0.00%
- Combination: 5.00%
- Undetermined: 0.00%
Comparison of data vs. Petersen (2001)

Table 4 presents a summary of number of hours on the water, number of hours observing dolphins, number of sightings, number dolphins sighted, frequency of sightings, and frequency of dolphins sighted for both this data set and Petersen’s data. The chi-square test to determine differences between the frequency of sightings and frequency of dolphin sightings resulted in p values of 0.941 and 0.917, respectively.

Table 4. Survey summaries for Garcia and Petersen data

<table>
<thead>
<tr>
<th></th>
<th>Garcia</th>
<th>Petersen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hours on the water</td>
<td>228.9</td>
<td>463.3</td>
</tr>
<tr>
<td>Number of hours observing dolphins</td>
<td>24.8</td>
<td>79.8</td>
</tr>
<tr>
<td>Number of sightings</td>
<td>74.0</td>
<td>169.0</td>
</tr>
<tr>
<td>Number of dolphins sighted</td>
<td>192.0</td>
<td>455.0</td>
</tr>
<tr>
<td>Frequency of sightings</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Frequency of dolphins sighted</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 5. Summary of behavioral observations for Garcia and Petersen’s data

<table>
<thead>
<tr>
<th></th>
<th>Garcia</th>
<th>Petersen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sightings for which assessments were possible</td>
<td>61.0</td>
<td>153.0</td>
</tr>
<tr>
<td>Number of Sightings involving <strong>Foraging</strong> or combination</td>
<td>35.0</td>
<td>132.0</td>
</tr>
<tr>
<td>Percent Forage</td>
<td>57.4</td>
<td>86.3</td>
</tr>
<tr>
<td>Number of Sightings involving <strong>Travel</strong> or combination</td>
<td>20.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Percent Travel</td>
<td>32.8</td>
<td>9.2</td>
</tr>
<tr>
<td>Number of Sightings involving <strong>Social</strong> or combination</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Percent Social</td>
<td>8.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Number of Sightings involving <strong>Rest</strong> or combination</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Percent Rest</td>
<td>3.3</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Of the 74 dolphin sightings, behavioral assessments were made for 61 of those sightings (82.4%). Of the 61 sightings, 35 involved foraging, 2 involved resting behavior, 5 involved social behavior, and 20 involved traveling. These numbers were compared to Petersen’s in Table 5 and the percentages of each behavior are illustrated in Figure 7. The chi-square test showed significant differences in foraging and traveling behavior between the two data sets, (p = 0.016 and <0.001, respectively). Resting and social behavior showed a lack of significant difference (p= 0.572 for rest; p = 0.088 for social).

Figure 7. Percentage of sightings involving each behavior for Garcia and Petersen data set

Sightings Distribution

out of the 74 sightings in the data set had latitude and longitude coordinates and were used to create the map. The majority of the sightings appear to occur on the west side of the mangrove islands, below Heusner’s Bogue. Six out of the eight sightings to occur within the SCWS were from the 2015 survey; one was recorded in 2006 and another in 2007. Foraging was the most common behavior observed within the sanctuary with four observations. Travel had three observations and social had one.

Figure 8. Distribution for 2005-2015 (Google Maps 2016)
For the 2005-2015 data set (Fig 8), eight sightings (22.0%) were located within shaded area and 29 (78.0%) were located outside the SCWS. The chi-squared test between these two percentages showed a significant difference (p <0.001).

Figure 9. Distribution for 2005-2015 encounters by year (Google Maps 2016)
The distribution map for only behaviorally-classified encounters is compared side by side with Petersen’s corresponding map in Figure 11. Thirty-three sightings were used to create the map. Petersen’s map also had most of the sightings occur on the west side of the mangroves, but the sightings were more disperse and not as concentrated below Heusner’s Bogue. The number of sightings in the shaded area were 8 for our data.
(24.0%) and 45 for Petersen’s data (29.0%). The number of sightings in the shaded area as percentages of total sightings showed no significant difference ($p = 0.492$).

Figure 11. Left – Distribution for 2005-2015 behaviorally-classified encounters (Google Maps 2016). Right – Petersen’s distribution of behaviorally-classified encounters (Petersen 2011)

Photo Analysis for Identification

A total of 12,743 photos were considered for photo analysis. After photos that showed only a portion of the fin, were too blurry, or the fin was positioned at an oblique angle were removed and after the author separated fins in photos that had multiple fins, the total number of photographs for review were 4,908. All of those photos were analyzed by at least two different judges. Of those photos, 495 received a Q-1 rating, 409 received a Q-2 rating, and 4,004 received a Q-3 rating. Those same photos were also given fin distinctiveness ratings; 2,517 were D-1, 1,083 were D-2, and 1,308 we D-3. After accounting for both quality and fin distinctiveness ratings, only 407 fin photos fit
the requirements to be matched and uploaded to the database (i.e. are Q-1 and either D-1 or D-2). The fins in those photos were matched and 46 individuals were identified.

**Testing for Criteria for Photo Analysis and Judges’ Agreement**

The experienced judges ranged between 13 to 28 years of photo identification experience. The novice judges ranged between 0 to 7 months of experience. The ANOVA calculated an F-ratio of 57.85 and a p-value of <0.001, meaning the variation between groups is greater than the variation within groups. The intraclass correlation (ICC) model produced an ICC value of 0.732, with a 95% confidence interval of 0.612 to 0.852. The ICC value falls under “substantial agreement” category in the divisions standard, with the confidence intervals falling under “substantial agreement” and “almost perfect agreement” respectively.

Based on the surveys, the average rate of ease for the photo quality guidelines was 3.9. The lowest rating was a 2, given by a novice judge, and the highest rating was 5 given by two experienced judges and one novice judge. There was no clear indicator on which of characteristics was easiest to score, all 5 characteristics were listed as the easiest in individual surveys. However, the front-runner for most difficult characteristic to score was proportion of the fin to the frame; five of the judges (3 experienced, 2 novice) listed it as the most difficult to score. Nine judges (5 experienced, 4 novice) thought having a cropped photo of the fin made it easier to rate the fin for photo quality; one of them stated that that’s the method they use. The judge that said using a cropped photo did not make it easier to rate the photo stated that she would have preferred to do the zooming in herself.

For the fin distinctiveness guidelines, the average rate of ease was also 3.8. The lowest rating was a 2, given by an experienced judge, and the highest rating was a 5, given by two experienced judges and one novice judge. 5 out of 9 judges (3 experienced, 2 novice) said it was easier to judge fin distinctiveness than photo quality. One judge chose not to answer the question because it was difficult to decide. 4 out of the 5 novice judges believed that fin distinctiveness should also be split up into characteristics to score similar to photo quality, and that number or size of the distinctive features should be one of the characteristics. 3 out of 5 experience judges, however, did not think using a similar approach as photo quality would be helpful. One suggested this would be time-
consuming, while another stated that it would be much more difficult to score because distinctiveness is more subjective.

The chi-squared test results to determine whether there are significant differences between rating techniques (zooming in or by using a cropped photo) are summarized for each judge in Table 6. Only 2 out of the 5 judges, Judges 1 and 4 showed significant differences between the scores for each rating technique (highlighted in yellow). However, Judge 1 only showed a significant difference for the Focus/Clarity category. Judge 4 demonstrated significant differences in scores for the Focus/Clarity, Overall Photo Quality, and Overall Fin Distinctiveness categories. The scores between rating techniques for Judges 2, 3, and 5 were different, but they were not significant.

Table 6. P values for differences between rating scores of photo analysis characteristics as well as overall photo quality and overall fin distinctiveness using different techniques (zooming in or cropped photo). Highlighted values represent significant differences.

<table>
<thead>
<tr>
<th></th>
<th>Judge 1</th>
<th>Judge 2</th>
<th>Judge 3</th>
<th>Judge 4</th>
<th>Judge 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus/Clarity</td>
<td>0.007</td>
<td>NA</td>
<td>0.241</td>
<td>0.004</td>
<td>0.827</td>
</tr>
<tr>
<td>Contrast</td>
<td>0.057</td>
<td>0.423</td>
<td>0.083</td>
<td>0.325</td>
<td>NA</td>
</tr>
<tr>
<td>Angle</td>
<td>1.000</td>
<td>0.911</td>
<td>0.372</td>
<td>0.582</td>
<td>0.638</td>
</tr>
<tr>
<td>Partial</td>
<td>0.083</td>
<td>0.263</td>
<td>1.000</td>
<td>0.103</td>
<td>1.000</td>
</tr>
<tr>
<td>Overall Photo Quality</td>
<td>0.104</td>
<td>0.275</td>
<td>0.160</td>
<td>0.013</td>
<td>1.000</td>
</tr>
<tr>
<td>Overall Fin Distinctiveness</td>
<td>0.263</td>
<td>NA</td>
<td>0.263</td>
<td>0.012</td>
<td>0.050</td>
</tr>
</tbody>
</table>

DISCUSSION

The time spent observing dolphins in 2015 is low compared to the total time spent on the water (6.4% of total survey time). This suggests that the dolphin population size in the Drowned Cayes is small in comparison to other coastal areas. Observation times for dolphins in Turneffe Atoll, for example, range between 23%-24% of total survey times (Campbell, Bilgre, and Defran 2002, Hancock 2007). Our percentage, however, is also low in comparison to values from previous studies in the Drowned Cayes. In studies completed between 1997-2000, percentages of total survey time were 22% and 17.2%,
respectively (Kerr, Defran, and Campbell 2005, Petersen 2001). When data were combined with 2005-2012 data, our percent of total survey time spent observing dolphins increased to 10.8%, but it is still lower than previous observations. Additionally, the average number of dolphins per sighting (1.6) is also low. This differs from 2.7 dolphins per sighting found by Petersen (2001) and 5.5 dolphins per sighting found by Kerr et al (2005). When combined, the 2005-2015 data made our dolphins per sighting value, 2.6, similar to that observed by Petersen.

Differences can be attributed to survey techniques. Although we spent more time closer to shore and through the bogues, as recommended by Petersen (2001), our survey times differed. Our 2015 surveys were completed around the same time every day, between 8am and 4pm. Petersen conducted two surveys per day, between 9am-12pm and 2pm-5pm. Although the different times only account for a difference of 2 hours, it could be that those two hours are times in which there is little dolphin activity in the Drowned Cayes. That would mean that we are increasing our survey time, but it is doing little or nothing at all to our total observation time. This idea is supported by the fact that only 3 out of the 11 (27.0%) sightings made in 2015 occurred between 12pm and 2pm. Those sightings occurred on two separate days and only lasted 36 minutes in total. Therefore, although our total survey time increased by 20 hours for the entire field time in 2015 by being on the water between 12pm and 2pm, only 36 minutes of observation time were gained (3.0% survey time).

Furthermore, our scan survey technique may have influenced our recorded observation times. Because we only observed the dolphin(s) for small amounts of time, only to determine behavior, we were the ones to determine when the sighting ended. Therefore we shortened our observation times. The percent observed time ends up being smaller than it could have been. Had we completed focal follows, our observation times would have been longer. However, our methods were derived from Petersen (2001). Their observations also only lasted long enough to determine behavior in an effort to maximize sightings, and Kerr et al (2005) used similar methods, staying with the dolphin long enough to collect photographic data.
This increased survey time and manipulation of observation time, does not explain the low number of dolphins per sighting. Most of the dolphins were found alone or in mother-calf pairs. In 2015, no more than 2 dolphins were observed at a time. This is different from Kerr et al’s (2005) largest group observation of 20 dolphins. The largest group from our entire data set was 8 and occurred in 2012. The low number of dolphins and the low observation times suggest that the dolphin population in the Drowned Cayes is low and has perhaps decreased since the 1990s. It is possible that this decline may be 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 five-minute encounter was observed. On the four days that recorded zero cruise ships, 9 dolphin encounters occurred lasting 2 hours and 55 minutes, accounting for 89.0% of the total observation time for 2015. This suggest that in the presence of cruise ships, dolphins may avoid the area.

Foraging was the most common behavior observed in our surveys. Traveling is often the most common behavior to occur in higher amounts naturally (Hanson and Defran 1993). Usually, traveling behavior occurs in combination with other behaviors, and is predominate commonly in the late morning and early afternoon. Although, our studies were completed in the late morning and early afternoon, foraging remained the main activity, taking over 57.0% of the activity budget. Traveling was the second most observed activity with 32.0%. This observation is consistent when sightings are divided by behavior type (Fig 7). Petersen (2011) also found a higher foraging percentage that the other behaviors, and suggested that the Drowned Cayes, Belize may be used primarily for foraging. The high number of mother and calf pairs also suggest that the study site is a foraging ground. In 2015, 8 out of 11 surveys (72.7%) included mother-calf pairs. Petersen (2011) had a 16.5% percent of calves and Kerr et al (2005) reported 22% of groups with calves, both higher than previous figures reported. Nursery grounds are usually located in areas with high productivity (Scott et al 1990). Areas of high productivity are used as foraging grounds (Stockin et al. 2009).

However, although foraging was the main behavior observed for both Petersen and our data sets, the percentages themselves have changed. In 1999-2000 the foraging percentage was significantly higher than the 2005-2015 data set, dropping 28.9%.
Interestingly, there was a 23.6% increase in traveling behavior between the two data sets. There are two explanations that can explain the drop in foraging activity and increase in traveling. The first involved food availability. Patchiness of food resources would cause an increase in travel behavior. If food resources have become less available in the area, this would cause the dolphins to have to increase their travel during foraging in order to find the areas of high productivity. The second explanation involves the increase of human activity in the area. As previously mentioned, more dolphin observations occurred on days when there were no cruise ships within the study area. If cruise ships are affecting the presence of dolphins in the area, and the area is predominately used for foraging, cruise ships may affect dolphins’ activity budgets. Dolphins may begin to avoid foraging grounds due to the increase in boat traffic, and may be traveling to surrounding waters. Previous research found that for both odontocetes and mysticete species, whale watching boat interactions caused a decrease in foraging and surface feeding behavior (Christiansen, Rasmussen, and Lusseau 2013). This 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. Not only is it an area of high productivity, but the Belize reef offers protection from predation, making it a safe spot for dolphins. The increase in traveling behavior and decrease in foraging behavior and presence of dolphins in general is concerning, as dolphins may begin to avoid safe areas due to human activity.

The Swallow Caye Wildlife Sanctuary has proven to be of minimal effect to the Drowned Cayes’ manatee population. Although a decrease of animals in the area due to increased boat traffic has not been observed, the area was already of high use to manatees. Additionally, the probabilities of capturing scarred manatees within or outside the sanctuary are the same, meaning manatees have not learned to seek shelter within the SCWS (Self-Sullivan 2007). The sighting distribution maps showed that for dolphins, the SCWS has also had no effect on their distribution or behavior. Majority of the observations made from 2005-2015 occur outside of the SCWS and there were no significant differences between the number of sightings within the SCWS for Petersen and our data. Dolphins have not been shifting their activity towards the sanctuary. Problems with the management of the sanctuary can be to blame for these results. Speed
limit signs and rules are posted in and around the sanctuary boundaries, but there are no patrols to enforce the rules. If the sanctuary provided better enforcement and/or boat traffic became minimal in the area, perhaps an increase of both manatees and dolphins would be observed. Our observation methods, however, could have also influenced our results. Because we did not spend an equal amount of time both within and outside the SCWS, it is unfair to compare the results. Only about a quarter of our time in 2015 was spent within the sanctuary. When thought of in those terms, then the proportion of sightings within the SCWS is considerably high – 6 out of 11 encounters were found within the sanctuary. In the future, attempts should be made to spend equal times within and outside the sanctuary to accurately compare the number of dolphins and encounters, and in order to determine the effect of the Swallow Caye Wildlife Sanctuary.

Additionally, the distribution maps showed majority of the sightings occurring on the west side of the Drowned Cayes. Although this may be representative of the dolphins’ behavior and habitat use, the results could have been affected by our survey methods. We followed a similar line of travel daily, along the west side of the coast, to reach the northern boughes. We would stop and record a sighting if we found a dolphin in the way. Therefore, that area was surveyed extensively and could have influenced the high number of sightings on that side of the study area.

The photo analysis guidelines used for this study and for the creation of the first database for the country of Belize seem to produce consistent and reliable results. Although the ANOVA determined that there was greater variation in the scores between the expert and novice judges, than within the groups the ICC value showed a high degree of reliability between judges. The ICC value fell under the substantial agreement category. Therefore, although there are differences between groups, the differences are not significant. The scores were similar between judges, regardless of experience level. This is similar to the results observed by Urian et al (2015). Urian et al circulated test data sets to researchers who had considerable experience with photo identification of bottlenose dolphins and other species. The researchers were able to use their preferred methodology. There was a high variation of degree among the responders in terms of the selection, scoring, and matching of images, however those that used similar methods
yielded less variability in the results. They recommended assigning scores of
distinctiveness and image quality before matching. Therefore, as long as a standard is
used, such as the guideline PowerPoint used in this study, the photo quality analysis
should be consistent amongst judges. Less experienced researchers can still provide the
same quality photos to the database as those that are more experienced. This can prove to
be useful, especially for location with large dolphin populations or with large photo
catalogs, as more people can rate the photos without fear of having inconsistent results.

Based on the judges’ responses in the surveys, the guidelines for both photo
quality and fin distinctiveness are relatively easy to use. Minor changes could be made in
order to make some of the characteristics easier to rate. The hardest characteristic to score
for half of the judges was proportion of the frame filled. This characteristic is important
to improve since it is heavily weighted. Based on the scoring system, if an image receives
a score of 5 in this category, the image will drop to Q-2 rating. Although the “rule of
thumb” trick was suggested in the guideline, judges still thought it was difficult to
determine what to do for photos which fall between 1–5% of the frame. One suggestion
was to create a grid to overlay on top of the photos to determine the score that should be
given. Another was to add another value category, such as 3 in order to have three
possible scores – 1, 3, and 5. The judge explains how this scoring system was more
useful in days when print film and slides were being used. Smaller fin photos would lose
their clarity once zoomed in, so it was better to eliminate them. However, now with
digital photography, smaller fins can be zoomed in without the same loss of resolution.
By creating a third value, the characteristic becomes less weighted, and allows for the use
of smaller fins that might have been overlooked. Lastly, a third suggestion was to use the
program FinBase. The program uses distance of the fin from the camera as a
characteristic to determine if the fin is too small to rate, therefore you do not need to
worry about the proportion of the frame filled. The three suggestions seem feasible, it
would be interesting to compare them side by side, to see which one gets better results.

Although fin distinctiveness was rated just as easy to use as photo quality, there
was a lot of opinions on the system used to score this characteristic. Most of the
experienced judges did not think it would be useful to break down this characteristic into
several categories just as with photo quality, whereas majority of the novice judges did.
Suggestions to score by the number and/or size of the features were made, as well as to include a fourth value category, below D-1, for those fins that have no distinctive markings at all, or are “clean”. Therefore, only “clean” fins could be removed from the data set used for matching, and D-1, D-2, and D-3 fins would be uploaded to the database. I would recommend leaving it as is. It appears that because fin distinctiveness is more subjective, it is easier to rate if you have more experience. Additionally, if improvements would be made to scoring photo quality, this would already allow more photos to enter the database. Allowing less distinctive fins into the database might cause incorrect matching (Urian et al. 2015). Because of that, the best way to make this characteristic easier to score would be to make the descriptions of the score categories more descriptive and to provide more examples of photos in the guideline for this characteristic.

Between cropping the photo vs zooming in on the dolphin fin for photo analysis, it appears cropping is the preferred choice. Nine out of ten judges used for the judges’ agreement test thought having a cropped photo made rating the photos easier. One judge stated that it is mostly for convenience; it is less time consuming than having to zoom in themselves. Another judge stated that in her experience she has found that cropping is often used. However, when photos were scored using both techniques, three out of five judges did not have significant differences in their scores. Out of the 2 judges that did have significant differences in their scores, only one characteristic was different for both of them, Focus/Clarity. If cropping can alter the Focus/Clarity score, cropping may have a bigger influence in photo analysis than at first suggested because previous authors have regarded focus or clarity as the most critical element of a good quality image (Urian et al. 2015). Therefore, further research should be completed to determine whether quality scores improve or not when cropping the photo.

CONCLUSION

Based on the data available, my analysis indicates 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. 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. Additionally, it should be investigated whether the dolphin population is using the Swallow Caye Wildlife Sanctuary more frequently than surrounding areas, and if so, additional management strategies to address dolphin conservation within the sanctuary should be addressed. The photo identification guidelines being used for the creation of the first bottlenose dolphin database in Belize appears to provide consistent and reliable results regardless of the experience level of the judge. This is convenient as it provides a standard that can be used by multiple researchers in the area.
APPENDIX A

PowerPoint presentation given to the judges explaining Rosel et al’s (2011) guidelines for photo analysis (Guideline created by Eric A. Ramos; Edited by Jazmin Garcia).

**Ratings**

1. **Proportion of Frame Filled (PF)** - The percentage of the area the fin occupies relative to the entire area of the image frame.
2. **Focus/Clarity (F)** - Sharpness or crispness of the photo. The focus/clearness of the photo can be reduced by blur from motion or poorly focused. A ratio at time of image.
3. **Contrast (C)** - The contrast of the image will range from low to high but too much. With contrast levels too high or very small stars may blend into the background.
4. **Angle (A)** - The angle of the dorsal fin relative to the camera.
5. **Partial (P)** - Partial ratings are given if the fin is obscured to the degree that it would be unlikely to reidentify the dolphin.
6. **Overall Distinctiveness (OD) -** Scores and markings tend to focus on the leading and trailing edges of the dorsal fin. A higher number of scars increases the distinctiveness of individual fins.
7. **Overall score (OS)** - The sum of all rating scores for each photo.

**Spreadsheets**

1. **Proportion of Frame (PF)**
   - 1 = more than 1% with small features clear
   - 2 = less than 1% with the fin/fin area poorly visible

2. **Focus/Clarity (F)**
   - 2 = in focus
   - 4 = moderate focus
   - 9 = blurry or out of focus

3. **Contrast (C)**
   - 1 = high contrast
   - 2 = sufficient contrast or minimal contrast

Examples of photo ratings are shown in the images provided.
APPENDIX B

Excel sheet template given to judges to input photo analysis results (Created by Jazmin Garcia).

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
<td>J</td>
<td>K</td>
<td>L</td>
</tr>
<tr>
<td>1</td>
<td>Photo</td>
<td>Fin # (left to right)</td>
<td>Proportion of Frame Filled (PF) 1 or 5</td>
<td>Focus/Clarity (F) 2, 4, or 9</td>
<td>Contrast (C) 1 or 3</td>
<td>Angle (A) 1, 2, or 8</td>
<td>Partial (P) 1 or 8</td>
<td>Overall Score (OS)</td>
<td>Rating</td>
<td>Quality</td>
<td>Overall Distinctiveness (OD) 1, 2, or 3</td>
</tr>
</tbody>
</table>
APPENDIX C

Survey given to the judges for Testing of Criteria for Photo Analysis and Judges’ Agreement (Created by Jazmin Garcia).

Judge’s Agreement/Raters Test Survey
Garcia 2016

1. On a scale from 1 to 5, how easy were the guidelines for photo quality to understand? 1 being not at all, 5 being extremely easy to use.

1 2 3 4 5

2. Rank the 5 characteristics (Focus/Clarity, Contrast, Angle, File Visibility, and Proportion) from easiest to give rating to, to the most difficult.

1. ________________
2. ________________
3. ________________
4. ________________
5. ________________

3. For the characteristic that was most difficult to rate, what was the main source of difficulty?

4. How would you try to improve this characteristic?

5. Did having a cropped copy of the photo, make it easier to rate the photograph?

6. On a scale from 1 to 5, how easy were the guidelines for fin distinctiveness to understand? 1 being not at all, 5 being extremely easy to use.

1 2 3 4 5
7. Was it easier to judge photo quality or fin distinctiveness?

8. Would having a set number of characteristics to rank, similar to the current methods for photo quality, make it easier to judge for distinctiveness?

9. What would be one of the characteristics you would include?

10. Are there any other comments or suggestions you would like to add?
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