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Effects of Boat Activity on the Behavior of Bottlenose Dolphins (*Tursiops truncatus*) in Waters Surrounding Hilton Head Island, South Carolina

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Abstract

During the summer of 1998, the effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) were investigated using 52 shore-based surveys along Hilton Head Island, South Carolina. Temporal autocorrelation indicated data collected on most variables should be analyzed in 6-min intervals. Responses to boats were categorized as "no response," "behavioral response," "change in direction of movement," or "change in both behavior and direction." Multiple boats had a greater influence on dolphin behavior and movement than the presence of a single boat. Dolphin-watching boats, motorboats, shrimp boats, and jet skis affected the group size and behavior of dolphin groups. Dolphin groups responded to dolphin-watching boats during 20% of observations, mainly with a change in both behavior and direction of movement. Motorboats caused a response in dolphins during 55% of observations, with a change in behavior or both behavior and direction. Jet skis had a more dramatic effect on dolphin groups, with 56% of groups changing their behavior and 11% changing both their behavior and direction. Shrimp boats always elicited a response. Dolphin groups changed both their behavior, and direction of movement to follow and feed behind these boats. In contrast, ships rarely caused a response, with groups changing their behavior but not their direction in 11% of observations. As the number of boats in the Hilton Head area increased, dolphin groups heightened responses—that is, changed both behavior and direction of movement. These boat-related effects on bottlenose dolphin behavior are considered "harassment" under the U.S. Marine Mammal Protection Act (1972) and should be scrutinized by agencies responsible for public education and enforcement of protective legislation.

Key Words: bottlenose dolphin, *Tursiops truncatus*, human impact, boat response, conservation, vessel traffic

Introduction

Bottlenose dolphins (*Tursiops truncatus*) inhabit bays, sounds, estuaries, and coastal waters of the Atlantic Ocean. They often are found in harbors and even ascend many miles into rivers (Leatherwood & Reeves, 1983). The human population is dense in these areas, and the water areas are heavily used for recreational and commercial boating. Research has focused primarily on the biology and ecology of these animals, so there is still a great deal to understand about the possible impacts of human activities, such as boating, on dolphin behavior.

Only a limited number of studies on the effects of boats on cetaceans are published (Au & Perryman, 1982; Baker et al., 1982; Bejder et al., 1999; Janik & Thompson, 1996; Kruse, 1991; Nowacek et al., 2001; Polacheck & Thorpe, 1990). Impacts of boat activity on marine mammals are of particular concern in coastal areas because of the large number of boats, their widespread use, high noise level, speed, and mobility (Richardson et al., 1995). Boats pose both direct and indirect threats to dolphins. Boats can cause dolphins to change movement patterns, alter behavior, or can even collide with dolphins (Gubbins, 2002). Powerboats emit high amplitude—that is, continuous underwater noise that could disrupt echolocation, mask communication, or cause temporary or permanent physical damage to a dolphin's ears (Ketten, 1998). Indirect effects of boat traffic include influencing prey movement, degrading habitat quality, or causing avoidance of critical feeding or breeding areas (Richardson et al., 1995). Janik & Thompson (1996) reported that the dominant behavioral responses of cetaceans to boat traffic were an increase in swim velocity, spatial avoidance, and change in diving patterns.

Hilton Head Island, South Carolina (32º 10' W, 80º 45' N), with its creeks, marshes, and coves, and the adjacent Calibogue Sound, is a typical coastal estuary habitat. Boat traffic there is heavy, including commercial shrimp boats, commercial dolphin-watching boats, motorboats, ships, ferries, jet skis, sailboats, kayaks, and wind surfers. Summer is the peak tourist season, resulting in high boat activity during the season when there is a peak number of bottlenose dolphins in the area (Gubbins, 2002). Herein, we report the results of research to study the effects of boat activities on the behavior and group structure of bottlenose dolphins in waters off Hilton Head Island.

Materials and Methods

Study Area

The study was conducted along the southern portion of Calibogue Sound, South Carolina (Figure 1). Bottlenose dolphin groups were observed from shore to eliminate any effect(s) of the observer/observation platform on the dolphins' behavior. Observations were made from South Beach, which is approximately 1610 m long, runs predominantly north to south, and provides a good location for observations of dolphin groups in an area of dense boat activity.

Data Collection

Data were collected from 1 June to 5 August 1998. Weather permitting, surveys were conducted for approximately 4 h each day. Existing beach markers, 160 m apart, were used to record the observer's location on the shore. Each survey started at Marker 7 and MCM walked along the beach north or south (direction chosen at random) and searched for dolphin groups offshore using binoculars. Once at the north end of the beach (Marker 0) or the south end (Marker 10), she stopped for approximately 5 min, reversed heading, and continued the survey, walking in the opposite direction until the entire survey area was covered at least four times each day. Surveys were conducted between 0700 and 2000 h in a pre-determined order to provide equal sample sizes throughout daylight hours and at each tidal stage. Observations were made when the Beaufort Sea state was ≤ 4.

Although dolphins that were far offshore were observed during the study, only bottlenose dolphins within approximately 100 m of shore were noted for this study. Data were collected using instantaneous/scan-sampling methods (Mann, 1999; Martin & Bateson, 1993), Canon 8 x 32 binoculars, and a stopwatch. A group was defined as all individuals in the same approximate area (≤ 10 m apart) engaged in the same behavior (Petricig, 1995; Smolker et al., 1992). Each group was observed from the initial sighting at 2-min

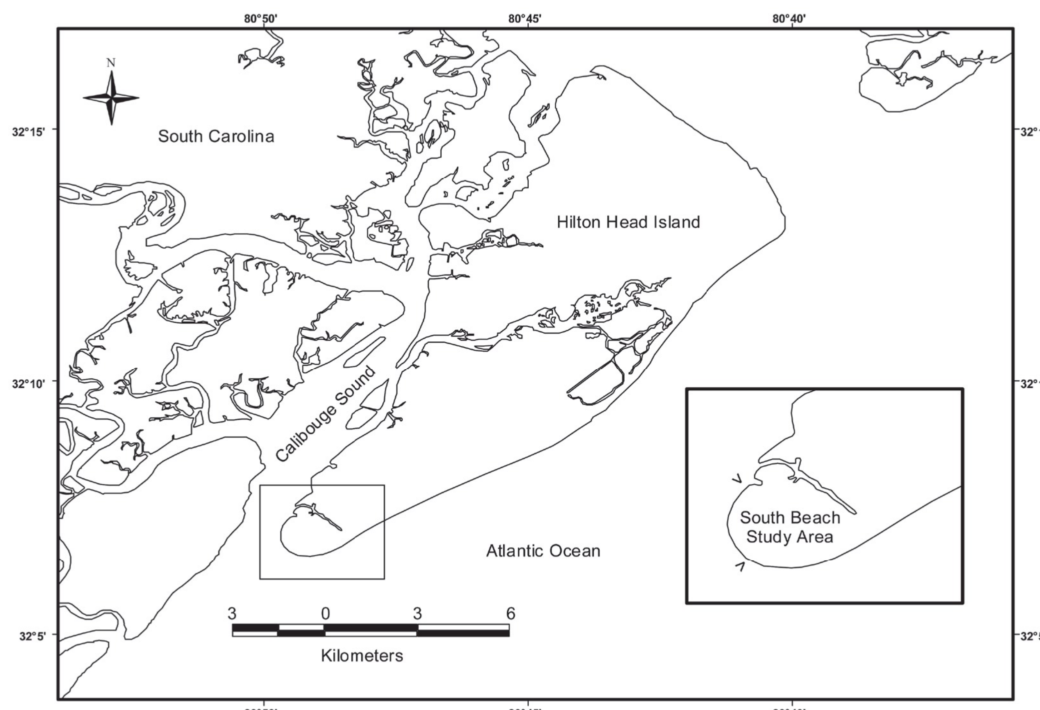

Figure 1. Map of Hilton Head Island, South Carolina; inset of South Beach Study Area; > < indicates the area of the walking survey.

intervals for a 12-min period. Once a group was observed for 12 min, or was no longer in view, the walking survey continued. If a second group appeared during the 12-min period, the presence of the new group was noted, but observations were continued on the first group.

Dolphin group behavior was categorized as "feed," "travel," "rest," "social," "sexual," or "other activities" (such as begging and approaching a boat). Feed was defined as engaged in foraging and broken down into single feed, barrier feed, cooperative feed, or shrimp boat feed. Travel was defined as swimming in a single direction at a constant speed, while rest was defined as floating stationary at the surface. Social behavior was defined as interactions among individuals or between groups of dolphins. Sexual behavior was defined as ventrum to ventrum rubbing or tandem swim by two dolphins, erection, and/or intercourse.

Four categories—"movement with the tide," "against the tide," "across the tide," or "no net movement"—defined direction of dolphin group movement. A change in movement direction was the altering from one movement category to another. Such changes in direction were important because they could indicate a response to a boat(s).

Inter-animal distance (IAD), or spacing of dolphins within a group, was categorized as "very tight" touching or < 1 m; "tight," 1 to < 2 m; "moderate," 2 to < 3 m; "loose," 3 to < 4 m; or "very loose," 4 to < 5 m (Gubbins, 2000). The same distance categories were used to estimate boat-animal distances (BAD) (e.g., a boat 2 to < 3 m from a dolphin was categorized as "moderate").

Nine categories of boats were defined. "Dolphin-watching boats" were inflatable zodiac boats (6 or 7 m in length) used by tourist companies. "Motorboats" were any sports-craft with an inboard or outboard motor. "Ships" and "ferries" were large (up to 26 m), slow-moving vessels. "Shrimp boats" were approximately 15 m in length and dragging trawl nets behind to collect shrimp. "Jet skis" were small, motorized personal water sports-crafts. "Kayaks" and "windsurfers" were nonmotorized personal watercraft. "Sailboats" generally were nonmotorized, but could be motor-assisted.

Data Analysis

Data were analyzed using analysis of variance (ANOVA) or a Pearson's chi-square contingency table (Zar, 1996), using *SYSTAT Version 11.0* software. Crockett (1996) cautioned that behavioral data collected in consecutive short intervals might result in observations that are not independent. We tested our data for temporal autocorrelation, using the autocorrelation function plot display (ACF) in *SYSTAT*. We found variables in our dataset were always autocorrelated at ≤ 2 min, rarely autocorrelated at 6 min, and never correlated at ≥ 12 min. Therefore, we subsampled our dataset into 6-min intervals (n = 798 observations).

We categorized responses by dolphin groups when boat(s) were present as (0) "no change in group behavior or movement," (1) "change in group behavior," (2) "change in group direction of movement," or (3) "change in both behavior and direction of movement of the group."

Although kayaks, sailboats, wind surfers, and ferries were observed, sample sizes were only large enough to examine the responses of dolphins to five boat types: (1) dolphin-watching boats, (2) motorboats, (3) jet skis, (4) shrimp boats, and (5) ships. The responses of a dolphin group to a single boat were compared to responses when multiple boats were present.

Results

Fifty-two surveys were completed, totaling 203 h of effort. Three surveys resulted in no sightings of dolphin groups. A total of 340 groups were documented, ranging in size from one to 14 dolphins, with 814 total individuals observed. The average number of groups per survey was 6.4 (SE = 0.49), with a mean of 2.9 (SE = 0.12) dolphins per group. Of the 215 boats observed with dolphin groups, 204 were motorized boats (108 dolphin-watching boats, 55 motorboats, 20 jet skis, 8 shrimp boats, and 13 ships); however, in the 6-min interval subset of our data, the number of boats observed with dolphin groups (n = 147) were 90 dolphin-watching boats, 28 motorboats, 9 jet skis, 11 shrimp boats, and 9 ships.

Temporal Autocorrelation

The data collected for the variables group size, inter-animal distance, and boat-animal distance were tested for temporal autocorrelation (Figure 2). Among variables, there was some inconsistency in the lag-time at which data were no longer autocorrelated. When no boats were present, IAD data were no longer autocorrelated at 10 min (five, 2-min intervals); with boats present, these data were no longer autocorrelated at 6 min (three, 2-min intervals). Group size data followed a similar trend, with no autocorrelation after 12 min (six, 2-min intervals) with no boats present, and at 8 min (four, 2-min intervals) with boats present. BAD data were no longer autocorrelated at 4 min (two, 2-min intervals). It was interesting that the lag-time of the autocorrelation analysis was shorter when boats were present, indicating dolphins changed their behavior more often compared to observations of undisturbed dolphins. We chose 6-min intervals to subsample our dataset to allow for detection of changes in behavior and movement

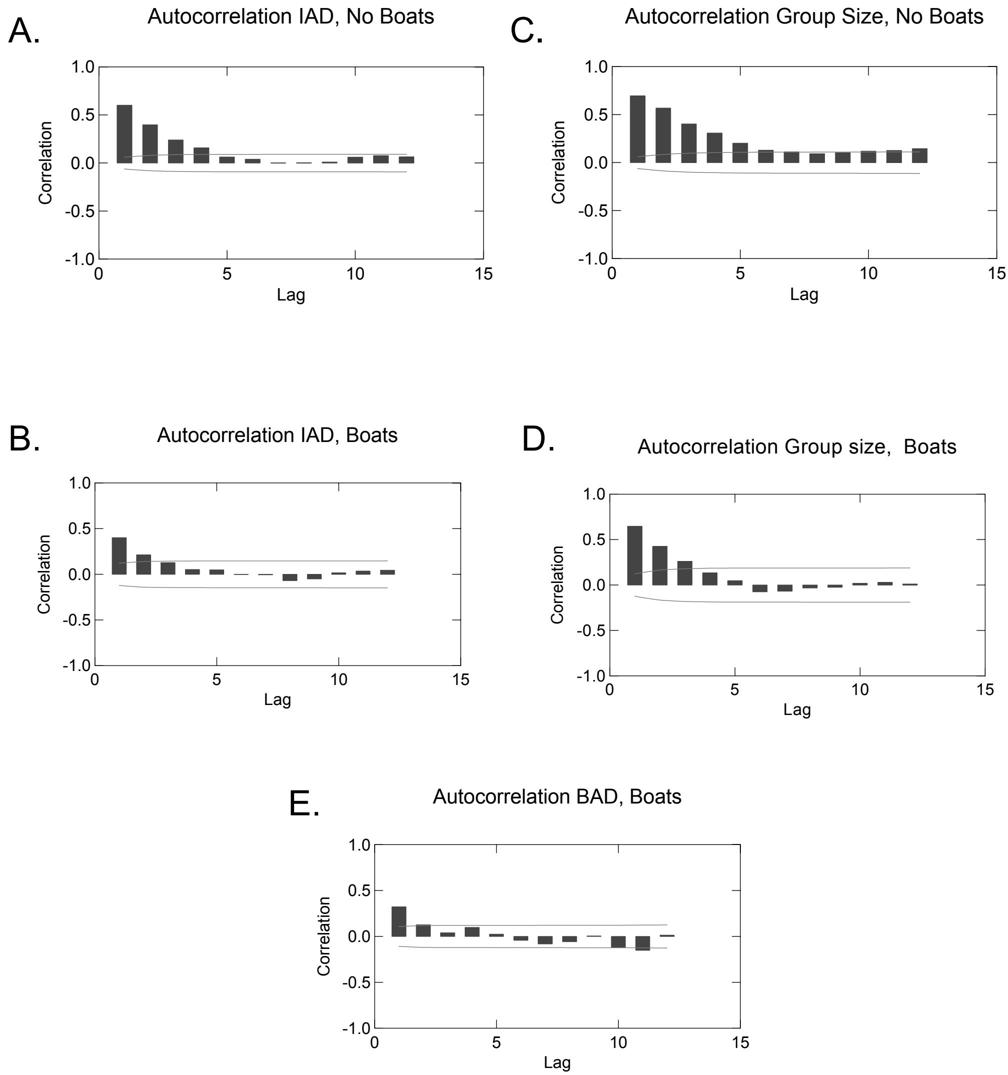

Figure 2. Temporal autocorrelation graphs of (A) inter-animal distance (IAD) with no boats present, (B) IAD with boats present, (C) group size with no boats present, (D) group size with boats present, and (E) boat-animal distance (BAD) over a 12-min period; each lag-time represents a 2-min interval; bars below the top horizontal line are no longer autocorrelated.

when boats were present, which reduced the dataset by almost one-third, but still provided adequate sample sizes.

Group Size

Group size was significantly larger ($F_{1,796} = 14.123$, $p = 0.000$) between observations with boats present and those without boats ($\bar{x} = 3.5$, SD = 2.74, range 1-14 individuals, and $\bar{x} = 2.8$, SD = 1.93, range 1-14 individuals, respectively).

Dolphin group size was not significantly different in the presence of any single type of boat; however, group size was significantly larger ($F_{9,92} = 4.341$, $p = 0.000$) in the presence of multiple boats compared to near a single boat.

Inter-Animal Distance

Analysis using chi-square contingency tables showed that the IAD of a group was not significantly different when boats were present versus absent, nor when different types of boats were present, nor when a single boat versus multiple boats were nearby, and did not change among the four response types.

Boat-Animal Distance

Dolphin group size was significantly larger ($F_{4,91}$ = 3.079, p = 0.020) with an increase in BAD. BAD significantly affected the type of dolphin response(s), both when only one boat was present ($F_{3,86}$ = 5.284, p = 0.002) and when many boats were present ($F_{3,92}$ = 11.632, p = 0.000). The closer the BAD, the more often dolphin groups responded by a change in behavior, change in direction of movement, or both.

Response of Dolphin Groups to Boats

Dolphin groups responded differently to boats (Figure 3), depending on the type of boat (X^2 = 52.837, DF = 15, p = 0.000) and whether a single boat or many boats were nearby (X^2= 69.647, DF = 18, p = 0.000).

There was a response by a dolphin group during 20% of dolphin-watching boat interactions (Figure 3). Of these observations, 6% showed a change in behavior, 4% a change in direction of movement, and 10% changed both their behavior and direction (Figure 3). The responses most often exhibited to motorboats were a change in behavior (22%) and a change in both behavior and direction of movement (22%). Shrimp boats always elicited a response: change in behavior (25%), change in direction (50%), or a change in both behavior and direction (25%). Jet skis had a dramatic influence on dolphin group behavior, causing a change in behavior during 56% of interactions, and a change in both behavior and direction during 11% of the observations. In the presence of jet skis, the majority of dolphin groups submerged and did not resurface in the area. In response to ships, the majority of dolphin groups showed no response (89%), while only 11% of dolphin groups changed their behavior.

The number of boats significantly affected ($F_{3,98}$ = 7.833, p = 0.000) the type of response(s) by a dolphin group. When a high number of boats was present, dolphin groups were more likely to respond with a change in both group behavior and direction of movement.

Discussion

The bottlenose dolphins near Hilton Head Island, South Carolina, are exposed to high boat traffic. This study examined the effects of such boat activity on their behavior and group structure. The results suggest that the dolphins' behavior was disrupted by the frequent boat activity in the area, with certain boat types creating different responses, and two or more boats nearby being more problematic than a single boat.

Temporal Autocorrelation

Crockett (1996) cautioned that care should be taken with analysis of behavioral data collected at consecutive time intervals to ensure that the observations are not interdependent. Therefore, it is important to document that what an animal does is not influenced by what it was doing during the previous observation interval. Few studies have examined temporal autocorrelation of behavioral data. Janson (1984) found the behavior of wild brown capuchins (*Cebus paella)* was autocorrelated at 5-min intervals. Slatkin

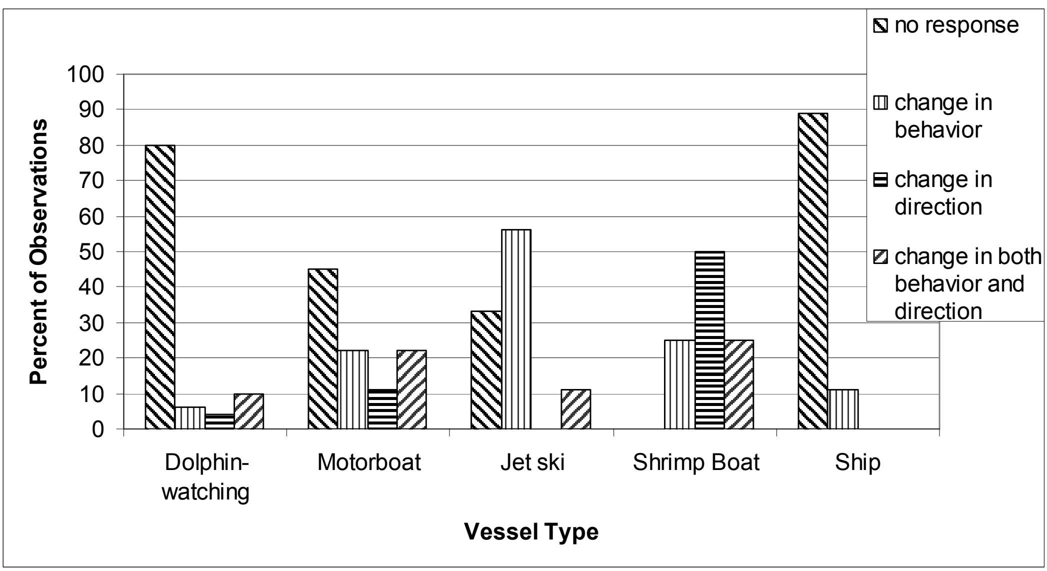

Figure 3. Effects of boat type on bottlenose dolphin group responses off of South Beach, Hilton Head Island, South Carolina

(1975) calculated that behavior of adult male geladas (*Therpothicus gelada*) was autocorrelated at 1-min intervals, but for yellow baboons, (*Papio cynocephalus*) behavior was autocorrelated at 4- to 5-min intervals. The behavioral data for the bottlenose dolphins in this study were autocorrelated over a longer lag-time when they were undisturbed and over a shorter lag-time when boats were present. The results reflect that dolphin group behavior was more changeable when boats were present. At 6-min intervals, dolphin behavior was no longer autocorrelated, so we subsampled our data at this interval, reducing the dataset by about one-third. Analysis of the full dataset produced different results and indicated that boats significantly affected some variables, such as IAD. We recommend that other investigators use temporal autocorrelation analysis to select the best time interval for collecting/analyzing or subsampling behavioral data.

Group Size

In Hilton Head, bottlenose dolphins had a larger mean group size when a boat was present. This may be due to boaters being more attracted to larger groups of dolphins or the dolphin-watching boats pursuing large groups of dolphins. Also, when more than one boat was present, dolphin group size was larger than when the group was near only a single boat. If one boater was attracted to a large dolphin group, other boaters might soon join them to view the dolphins.

Inter-Animal Distance

Many cetacean species travel in tight groups (Leatherwood & Reeves, 1983). Tight group formation was observed near boats in groups of Hector's dolphins (*Cephalorhynchus hectori*) in Porpoise Bay, New Zealand (Bejder et al., 1999), and *T. truncatus* in Sarasota Bay, Florida (Nowacek et al., 2001). Tight group formation often is observed in species of dolphins in response to approaching boats, and during situations of surprise, threat, or danger, possibly providing more protection for each individual in the group (Johnson & Norris, 1986); however, surprisingly in this study, the IAD among bottlenose dolphins did not change significantly in the presence of boats.

Boat-Animal Distance

Mean group size was larger when boats were farther away (i.e., BAD was longer—moderate to loose). With an increase in the distance between boat(s) and the dolphins, larger groups would have more space to maneuver, whereas small groups would be more cohesive and more maneuverable closer to boats. With a decrease in BAD, the response by dolphin groups escalated. Dolphin groups responded more often to close boats with both a change in behavior and a change in their direction. Similarly, harbor porpoises (*Phocoena phocoena*) in the western Bay of Fundy expressed greater avoidance responses to vessels at closer distances (Polacheck & Thorpe, 1990).

"Harassment" or the "potential to harass" cetaceans under the Marine Mammal Protection Act (MMPA) (Anonymous, 1972) is prohibited. Boats are restricted from moving within 100 feet (30.5 m) of any cetacean. Despite these laws, boats in the Hilton Head area often moved close to dolphin groups.

Response of Dolphin Groups to Boats

Dolphin responses varied depending on the type of boat(s) present. Of all boat types, dolphin-watching boats were observed most often with dolphin groups. Cetacean-watching tours worldwide have grown tremendously over the past 40 years (Hoyt, 1995). In our study, the majority of interactions with these boats did not cause a response. We expected that dolphins in this area would respond more to these boats because dolphin-watching boats actively searched for and pursued dolphins, attempting to get as close as possible; however, these dolphins may be habituated to the presence of dolphin-watching boats and, thus, displayed less obvious responses.

Motorboats did influence dolphin group behavior. The reaction(s) displayed by dolphin groups increased with the number of motorboats. Often, dolphin groups responded to motorboats by a behavioral change or a change in both behavior and direction. Belugas (*Delphinapterus leucas*) are hunted in estuaries from small motorboats, yet return annually to these areas (Richardson et al., 1995); however, Richardson et al. reported that belugas fled in response to fast, erratically moving small powerboats. The underwater noise and fast movements of motorboats could disrupt feeding, socializing, and other dolphin behaviors.

Jet skis had a notable effect on dolphins, and they appeared to elicit strong and immediate reactions compared to other boat types. Jet skis often approached the dolphins at high speeds and with erratic movements. In response to jet skis, there was a dramatic increase in the change of group behavior; often, they submerged and did not resurface in the study area. Research on the effects of jet skis on marine mammals is scarce. Jet skis have become popular, especially in tourist areas. There has been concern about disturbance to humpback whales (*Megaptera novaeangliae*) in Hawaii due to jet skis, yet there are no data on whale responses (Richardson et al., 1995). Communication through sound and behavioral display is important to most cetaceans. With jet skis in the area, Hilton Head dolphins remained below the surface for longer periods of time. This could have been an avoidance response to these watercrafts, or it could represent prolonged periods spent under water due to communication difficulty. Because of their high speeds, loud engine noise, unpredictable movements, and misuse, these crafts could pose serious threats to dolphins and other marine animals that spend a large amount of time at the surface.

Dolphins and porpoises in many areas feed behind shrimp boats (Fertl & Leatherwood, 1997). When a shrimp boat was present, Hilton Head dolphin groups always responded, most often with a change in both behavior and direction of movement. Dolphins fed on prey that surfaced due to the trawling and not the discarded by-catch.

Slow moving, large vessels, like ships or ferries, caused little to no obvious response in dolphin groups in this study. Ships in the Hilton Head area rarely got within 5 m of dolphin groups, and when they did approach a group, they moved slowly or idled.

The behavioral changes in dolphin groups increased as the number of boats increased. With numerous boats around, dolphins changed both their behavior and direction of movement. Similarly, disturbance in humpback whales also increased with increased vessel traffic, even causing a sudden abandonment of the Glacier Bay, Alaska, area in 1978 (Baker et al., 1982). Beluga whales in the St. Lawrence estuary also displayed increased disturbance with higher numbers of boats present (Richardson et al., 1995).

Although dolphins change their direction of movement to feed behind shrimp boats, in the presence of other boat types, changing their direction of movement in response to approaching boats could be a hindrance. Dolphins travel to locate food and conspecifics, and perhaps to avoid predation or for thermoregulation (Shane, 1990). Boat traffic could impede dolphin travel or feeding or could alter surface time and rest. The presence of boats also may be disruptive to social activity by posing risks to vulnerable animals at the surface. In some cases, humpback whales in southeastern Alaska displayed clear avoidance to vessels by changing direction and moving away (Baker et al., 1982). Au & Perryman (1982) determined dolphin schools in the eastern tropical Pacific Ocean, particularly spotted (*Stenella attenuata*) and spinner (*S. longirostris*) dolphins, frequently swam rapidly away from an approaching ship. In our study, dolphins responded to more than one boat in the area with a change in both behavior and direction of movement. Perhaps the cohesive movement of a large dolphin group is hindered when many boats are nearby.

Although many cetaceans show considerable tolerance to boat traffic, on many occasions they avoid boats or change their normal behavior. In Hawaii and Alaska, for example, there is increasing concern that the recent changes in humpback whale distribution could be due to the increase in local human activities (Baker et al., 1982). Short-term effects on killer whales (*Orcinus orca*), bowhead whales (*Balaena mysticetus*), and bottlenose dolphins from approaching boats included an increase in their swim speed, decreased surfacing with fewer respirations, and a change in direction (Kruse, 1991; Nowacek et al., 2001; Richardson et al., 1995). Sperm whales (*Physeter macrocephalus*) displayed startle reactions to approaching vessels (Whitehead et al., 1990). Bejder et al. (1999) expressed concern that "dolphins that are forced to spend a great deal of time and energy avoiding boats may end up with reduced biological fitness as a consequence of the disruption of critical energy budgets" (p. 748).

Recommendations

Results from this study suggest that boats in the Hilton Head Island area affect the behavior of the dolphins. Short-term effects were noted, but long-term cumulative effects need to be addressed. These effects could include reduced reproductive success, reduced feeding and rest opportunities, and/or total abandonment of vital coastal habitats. Further studies are needed to determine the extent of short-term effects and long-term disruption caused by human activities. These studies should include an in-depth examination of the influences of boat activity on dolphin behavior by use of aerial surveys, controlled boat approaches, and determination of underwater noise effects. Habitat degradation due to human activities needs to be assessed in both surrounding waters and along the coastline. Stricter regulations and enforcement should be placed on human activities in coastal areas and on boating activities, particularly commercial dolphin-watching boats and jet skis. The public needs to be educated and reminded of the laws and regulations concerning dolphins and other wildlife in the area.

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