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UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

STATUS AND ECOLOGY OF *SOTALIA FLUVIATILIS* IN THE CAYOS MISKITO RESERVE, NICARAGUA

A Dissertation

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfilment of the requirement for the

degree of

Doctor of Philosophy

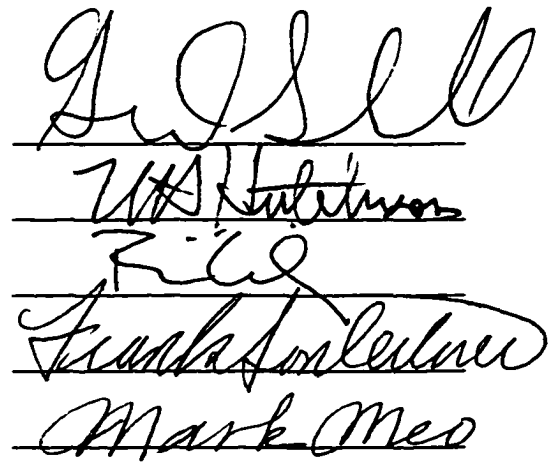
By

HOLLY H. EDWARDS
Norman, Oklahoma
1999

STATUS AND ECOLOGY OF *SOTALIA FLUVIATILIS* IN THE CAYOS MISKITO RESERVE, NICARAGUA

A Dissertation APPROVED FOR THE DEPARTMENT OF ZOOLOGY

BY



PREFACE

This dissertation is presented as a single paper. This paper will be submitted to the refereed journal *Marine Mammal Science* and is formatted accordingly. The appendix of basic survey data is not part of the submitted manuscript.

ACKNOWLEDGMENTS

Many people were instrumental in the successful completion of my research and dissertation. Without the technical assistance and financial support from them, this project would not have been possible. With much appreciation and respect I would like to thank my doctoral committee: Gary Schnell (advisor), Richard Cifelli, Victor Hutchison, Frank Sonleitner and Mark Meo. Their guidance and support through my program at OU were invaluable and I am honored to have had each of them serve as a mentor. A special thanks to Gary Schnell without whom none of this would have been possible. His input, patience and editorial skills, as well as his faith in my ability, have made this project a reality. Over the years he has spent many hours helping me achieve my goals, and I am very grateful for the time he has invested in my education and professional growth.

Many of the staff members of the Oklahoma Biological Survey provided technical and clerical support for my project. In particular, Dan Hough and David Certain gave input on data analysis and GIS, thus helping make the results of my research more meaningful. I would like to thank Marsha Womack and Janice Spurlock for helping me prepare for my trips to Nicaragua and for keeping me connected with the rest of the world while there. I also am grateful to Coral McCallister for the work she did on the figures associated with this dissertation.

I am greatly indebted to Armstrong Wiggins, a fine Miskito man, who made my work along the Miskito Coast a possibility. His assistance with establishing necessary relationships with the people of the Caribbean coast of Nicaragua enabled me to work

within the Cayos Miskito Reserve. Without Armstrong my work in Nicaragua would not have been possible. Armstrong has been a good friend and ally, and I thank him for his contribution to my project.

There were several people who aided my work in Nicaragua by helping me obtain the necessary permits and allowing me use of equipment and supplies, particularly Milton Camacho and Balbo Müeller of the Servicio de Areas Silvestres y Fauna, Ministerio del Ambiente y Recursos Naturales (MARENA). I thank them for their contributions. I also thank the late Stephen Leatherwood, the late Ken Norris, and Keith Mullin for their input on preliminary proposals. Their recommendations were very helpful in developing this project.

I appreciate the dedication and hard work of my field assistants Sergio Chow, Denis Castro, and the many boat drivers who worked tirelessly to help collect data. I also thank Teri Bolton and Marco Villaneuva from the Institute of Marine Sciences, Roatan, Honduras, who traveled from Honduras to assist me with the aerial survey. Without their help that portion of the project could not have been undertaken. They provided me an invaluable skill and their contribution is gratefully acknowledge.

Maritza Urbina and Aura Arguello were wonderful friends, and I thank them for making me feel at home in their country. I owe a special thanks to the Boudier family for opening their home to me and my fellow workers, for driving boats, and for sharing insight about the culture of the Miskito Coast and its people. I also thank Juan Perez, Jr., Alie Travis and Eydie Proffitte, all of whom were kind enough to spend their time and money to travel to Nicaragua to help with this project. They not only assisted me with

data collection, but they provided good company during long trips to remote areas.

I am grateful to my parents for years of emotional and financial support during my schooling. Without their help, I would have been unable to pursue my educational and professional goals. I could not have spent the time that I did conducting my research in Nicaragua without them.

I recognize and thank the following people and organizations for their generous financial support of this project: American Indian Graduate Center, American Museum of Natural History, Bryan Crowley, PADI Foundation, Oklahoma Biological Survey, University of Oklahoma Foundation, Graduate College, Graduate Student Senate, and Department of Zoology. Their contributions helped make this project a reality.

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STATUS AND ECOLOGY OF *SOTALIA FLUVIATILIS* IN THE CAYOS MISKITO RESERVE, NICARAGUA

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ABSTRACT

In March through May of 1996-98 we conducted research in the Cayos Miskito Reserve, Nicaragua to assess the status, ecology and distribution of *Sotalia fluviatilis*, a dolphin known from southern Brazil to Honduras. Surveys of lagoons, inlets and coastal areas were conducted and observational information collected on *Sotalia* activity, behavior, and other factors relating to its ecology. During surveys, 183 groups (536 individuals) were sighted (for areas with *Sotalia*, mean overall density = 0.593/km^2, coastal areas = 0.591/km^2, inlets = 0.666/km^2, and lagoons = 0.484/km ^{2}). Overall, mean herd size was 3.1 (SD = 1.8, range 1-15) and varied among years, but not for different months. We estimate that 48 to 55 *Sotalia* inhabited the portion of the Reserve we studied. Sightings of *Sotalia* were nonrandom (nearest-neighbor analysis); clumping of sightings indicates that some areas were preferred. In both Wauhta lagoon and Pahara inlet, sightings were more frequent after 1200 h than 1200 h and before. In coastal areas, *Sotalia* were sighted more often within 100 m of shore (54.0%) and less often from 201-300 m (6.8%). Feeding was the predominant of five recorded activities (*i.e.*, traveling, feeding, socializing, resting and other) based on time of sighting (70.3%) and during instantaneous sampling (56.3%). Resource distribution appears to be an important factor influencing *Sotalia* distribution in the Reserve.

Key words: *Sotalia fluviatilis*, Cayos Miskito Reserve, Nicaragua, tucuxi dolphin, habitat use.

INTRODUCTION

Sotalia fluviatilis (the South American or tucuxi dolphin) is a small dolphin with a coastal marine form and a smaller freshwater form (da Silva and Best 1996). Little is known about the distribution, abundance and ecology of either. The marine form appears to have a coastal distribution, inhabiting bays, estuaries and in-shore waters (Leatherwood *et al.* 1976). Its range extends along the Atlantic and Caribbean coasts from Florianópolis in southern Brazil (Simões-Lopes 1988) to central Honduras (B. Corbin and E. Bolton, personal communication). Carr and Bonde (1999) reported that, in 1992, *Sotalia* were common along the eastern coast of Nicaragua (the Miskito Coast) in an area that in 1991 was set aside as the Cayos Miskito Reserve (Fig. 1). Given that *Sotalia* have been sighted in Panama, Costa Rica, Nicaragua and Honduras, they appear to be a permanent resident in Central America, but no detailed studies have been conducted in the northern part of their range.

The Cayos Miskito Reserve in Nicaragua is located within one of the larger tracts of wilderness remaining in Central America (Carr 1994). The Miskito Coast itself contains one of the richest shallow-water marine regions in Central America and the Caribbean. The mangrove-lined lagoons and rivers that characterize the coastline of the Reserve form a continuous estuarine region. Similar habitat is found throughout much of Central America, extending north to the Yucatan Peninsula in Mexico. Large mangrove-lined bays are common to the north of the Reserve in an area known as the Honduran Miskitia (La Mosquitia) and south of the Reserve in the southern portion of Nicaragua. Estuaries in the Reserve and surrounding areas are part of a rich marine ecosystem; they

have high concentrations of nutrients and zooplankton, and provide food, shelter and breeding areas for numerous species of fish and invertebrates. Dolphins of a number of different species often occur in estuaries (Ballance 1992), and the lagoons and coastline of the Cayos Miskito Reserve support significant numbers of *Sotalia* (locally called "Lam" in Miskito or "bufeo negro" in Spanish).

Although human disturbance in the Cayos Miskito Reserve is less than in many other parts of Central America, this is changing. Human activities in and around the Reserve are contributing to significant environmental change. With the termination of civil war in 1990 and the return of Nicaragua to a democratic state, the Miskito Coast has experienced a substantial growth in population and free enterprise, including increased logging, mining and fishing by local and foreign industries. From 1971 to 1995, the human population of the Miskito Coast increased from 55,000 to 193,000. Coupled with this increase in population was growth of the fishing industry. This is reflected by the fact that, from 1969 to 1995, exportation of fish, shrimp, turtles and lobsters increased from 2.7 million kg to 9.0 million kg annually (Anonymous 1997).

Like many of the world's cetacean species, *Sotalia* in Nicaragua are threatened by human activity. Interviews with local people indicate that *Sotalia* numbers are declining and that the species is no longer found in some of the areas within the Reserve that it previously occupied. Local people do not actively hunt *Sotalia*, but they are caught incidently and drown in gill nets. As fishermen have been introduced to new netting materials and as demand for seafood from this region has increased, so has the incidental catch. As a result, *Sotalia* numbers have been adversely affected in this portion of its

range. Continued change in and around the Cayos Miskito Reserve, and increases in human activity in the region, could lead to the local extinction of valuable species, possibly including *Sotalia*.

The Cayos Miskito Reserve is a unique area. It contains four large lagoons, (that vary in salinity, temperature, water depth, vegetation and bottom substrate), 190 km of coastline, and offshore waters. The large diversity of habitat types makes the Cayos Miskito Reserve an excellent area in which to evaluate factors that affect the distribution, ecology and activity of *Sotalia*. In the spring of 1996 we initiated a project to assess the status of *Sotalia* in the Reserve and investigate factors that influence its ecology and distribution. This project entailed: (1) conducting surveys to obtain a baseline population estimate; (2) evaluating *Sotalia* habitat preferences; and (3) studying distribution and movements. Secondarily, observational data on activities, behavior and social interactions of *Sotalia* were recorded. The overall goal was to increase our knowledge of *Sotalia* biology and contribute information relevant to *Sotalia* conservation in the Cayos Miskito Reserve.

MATERIALS AND METHODS

Study area and field season--The Cayos Miskito Reserve is located along the Atlantic coast of Nicaragua in the Región Autónoma del Atlántico (North Atlantic Autonomous Region or RAAN). The boundaries of the Reserve extend from the Honduran border south to 2 km south of the community of Wauhta (N13°28', W83°31'). The Reserve, established by presidential decree, includes offshore waters, a cluster of

islands known as the Miskito Keys, and 190 km of coastline, including four large lagoons (Wauhta, Karata, Pahara, and Bismuna), as well as a number of smaller adjacent lagoon areas and their associated estuaries (Fig. 1).

The coastal areas of the Reserve are covered by a series of large lagoons and rivers lined with mangroves (predominantly red mangrove [*Rhizophora mangle*] and black mangrove [*Avicennia germinans*]) and gallery forest. The shallow-water area along the coast contains a flat sand-and-mud bottom with water depths ranging from 1 to 10 m. The salinity of the coastal inshore waters and lagoons varies throughout the year, being highest during the dry season (33 ‰) and lowest during the rainy months (0 ‰). The heaviest rains occur in June through August. They are followed by a short dry season in September and October, and cooler, wetter weather from November through February. The driest months are March through May. Annual rainfall ranges from 250 to 350 cm. During our dry-season study, water temperatures ranged from 25° to 32° C ($\bar{x}$ = 29.4° C).

Puerto Cabezas, a town of about 40,000 (Censos Nacionales 1995), is situated in the center of the Reserve. This town serves as the capitol of the Autonomous Region of the North Atlantic (RAAN) and is the only urban community located in the Reserve, although a number of small rural communities of indigenous Miskito Indians dot the coastline and lagoon shores.

Data for this project was collected during the dry season of April and May in 1996, and March through May in 1997 and 1998. The dry season was chosen to avoid the winds, heavy rain and logistical problems that would hinder data collection during the rainy season.

Survey design and methods--A preliminary aerial survey was flown on 9 and 10 April 1996 to obtain an overview of the area and assess how best to design and implement boat surveys. The aerial survey covered the Reserve from Bismuna lagoon (N14°56', W83°00') south to the Prinzapolka River (N12°24', W83°34') and was flown in a high-wing Cessna 206 owned and operated by La Costeña Airlines of Managua, Nicaragua. Two observers were seated in the rear of the plane, one on each side, and a third sat next to the pilot. Flights involved 7 h and 10 min of survey time over two days (9 April 1996, 1515-1700 h; 10 April 1996, 0830-1110 h and 1415-1700 h). The survey was conducted at an altitude of 150 m and speed of 90 knots (166 kph). The coastline was surveyed by flying 0.5 km offshore and parallel to it. Lagoons were traversed systematically, and rivers and lagoon inlets were surveyed by following the contour of the shoreline.

Boat surveys with strip-transect methods (Eberhardt *et al.* 1979, Hammond 1986) were conducted during April and May in 1996 and March through May in 1997 and 1998 in calm weather (Beaufort 0-3). Boat speed during the survey varied from 9-16 km/h. The survey area was divided into 10 sections (Fig.1), each representing a segment of the study area that could be surveyed in a systematic way: (1) Pahara lagoon (96.4 km^2); (2) Pahara inlet (2.0 km^2); (3) Pier to Pahara (5.3 km^2); (4) Puerto Cabezas to Wawa (5.0 km^2); (5) Karata inlet (2.3 km^2); (6) Karata lagoon (33.6 km^2); (7) Wawa to Haulover (6.7 km^2); (8) Haulover to Wauhta (4.5 km^2); (9) Wauhta lagoon (67.9 km^2); and (10) Wauhta inlet (1.1 km^2). Along coastline areas, each section was surveyed by traveling along a line 150 m offshore, since preliminary surveys indicated that animals could

reliably be sighted up to 150 m under average weather conditions. Each strip was 300 m wide (150 m from each side of the boat). Usually, the entire length of a section was surveyed; however, on occasions only part of the section was covered. Preliminary trials, aerial-survey results and interviews with local fisherman established that *Sotalia* were most common near shore (within 300 m); therefore, offshore surveys were not conducted.

The areas around the mouths of inlets were shallow and, in many cases, non-navigable by boat because of large sand bars. Waters were rougher in and around these areas. Thus, by necessity, surveys and observational trips around the mouths of Wauhta, Karata and Pahara inlets were conducted only in deep channels. In the inlets themselves, strip widths were equal to the widths of the inlets (no inlet was wider than the 300 m).

In the lagoons, strip width was reduced to 100 m on each side of the boat, which helped compensate for decreased sight ability due to greater water turbidity, choppiness and glare. Each strip was positioned adjacent and parallel to the previous strip to obtain complete coverage of the area surveyed. The relatively low number of group sightings per day and the slow travel rate of *Sotalia* made recounting groups unlikely. Since lagoon areas were very large and could not be covered in a single survey, the area covered during individual surveys varied, ranging from 6.2-16.8 km^2 in Pahara lagoon, 2.5-10.8 km^2 in Karata lagoon, and 0.79-14.6 km^2 in Wauhta lagoon.

During the 1996 field season, all surveys were conducted from cayucos or hand-made canoes 6 m long and propelled by 45-75 horsepower outboard motors. We surveyed the coastline from Pahara inlet to Wauhta inlet, as well as Pahara lagoon and inlet, Karata lagoon and inlet, and Wauhta lagoon and inlet. Surveys were conducted by

two people, one seated on each side of the boat and searching from 0° (bow) to 135° on their respective sides.

During 1997 and 1998 most of the surveys north of Wauhta lagoon were conducted from fiberglass or wooden skiffs 6 m long and 1.5 m wide. One observer was positioned at the bow of the boat and searched 45° to the right or left of center. The other observer was positioned at the center of the back of the boat and searched from 45° to 135° on the right side and from 225° to 315° on the left side of the boat. This configuration was chosen to maximize coverage and to maintain proper balance of the boat under all weather conditions. Surveys in and around Wauhta lagoon were conducted from 6-m wooden cayucos using the same positioning of observers.

Data recorded during the surveys included the starting and ending time, sea state (Beaufort scale), tidal state, species sighted if other than *Sotalia*, location and time of sighting, distance from the shore, herd size, number of adults and calves (operationally, calves were defined as animals two-thirds or less in length of an adult in close association), activity of the animals, habitat characteristics (*e.g.*, water depth, turbidity, salinity and temperature), and bird associations. A Garmin GPS 100 Survey II Personal Surveyor was used to obtain sighting position, vessel speed, and vessel direction. Water temperature was measured with a thermometer held below the surface of the water for a minimum of 2 min. A Bushnell Lytespeed 400 Laser Ranging System was used to evaluate distances to the shore. When animals were sighted, the boat was directed to the location of the animals. Search effort stopped while observers counted animals and recorded the above information. A sighting record included all individuals that were seen

in the vicinity of the first animal sighted (operationally, we considered a group of *Sotalia* to be a herd). Obtaining an accurate count was not difficult given that herd size typically was small (1 to 15 individuals, $\bar{x}$=3.1) and the animals tended to tightly aggregate. We spent no longer then 15 min counting animals and recording data; this provided ample time for counting without compromising the integrity of the survey design. After recording needed data, the boat returned to its original position on the strip and surveying resumed.

Density estimation--The density of *Sotalia* was estimated using the data collected on boat-survey strip transects. The density per section was calculated as the total number of *Sotalia* sighted in all surveys divided by the sum of the areas covered in all surveys. Densities obtained from these surveys are minimum estimates given that, undoubtedly, some animals were missed during boat surveys due to weather or sea-state conditions that resulted in the observer's view being obstructed, animals being submerged, or movements of the animals in response to the survey vessel.

Ecology, distribution, habitat usage, and activity--Data from both strip-transect and separate observational boat surveys were used to ascertain information about *Sotalia* herd size and distribution. Nearest-neighbor analysis (ArcView software and script; Clark and Evans 1954) was used to help assess any relationship of environmental variation to distribution by testing for the spatial randomness of *Sotalia* sightings.

Observational trips also were used to collect information on behavior and activity of focal groups (Altmann 1974). A focal group was defined as any group of animals in close association with one another (*ca.* 10 m) moving in the same direction and/or

engaged in the same activity. Focal groups were easy to identify since most animals stayed in close association and engaged in similar behavior. At 3-min intervals we conducted instantaneous sampling of focal-group activity. Shane (1990) recommended instantaneous sampling over other sampling methods when observation periods are relatively short, which usually was the case in our study (*i.e.*, only a few minutes).

Activities of focal groups were classified into one of five categories: traveling, feeding, socializing, resting, and other. Traveling animals were ones moving steadily in a constant direction as a group, diving and resurfacing synchronously as they moved. Feeding animals were characterized by no net movement of the group in any one direction. During feeding the dolphins generally surfaced and dove asynchronously in slow, rolling motions during which only the dorsal fin and back were visible. Feeding animals would move along the beach or shoreline at speeds slower than when traveling. The presence of birds feeding with or following the dolphins was a good indicator of feeding behavior. Socializing animals were characterized by interactions between individuals, usually in the form of body contact, including slapping, breeching, chasing, and rolling onto or over one another. Resting animals had their head and dorsal fin above the water surface; there was little or no activity by the animals and no forward motion (animals usually bobbed or floated motionless at the surface for a number of seconds). The "other" category was reserved for behaviors that could not clearly be placed into one of the other four categories. Combinations of behaviors were included in this category (*e.g.*, traveling/feeding). Traveling and feeding sometimes occurred together as animals moved from one location to the next, stopping to feed periodically, then moving on. We

alternated between following a group for as long as possible, and finding and following multiple groups for shorter time periods. Information from instantaneous sampling, as well as activity at the time of sighting, was used to estimate the percentage of time spent engaged in each activity.

Sightings of *Sotalia* along the coast were classified into three distance categories (0-100 m, 101-200 m, 201-300 m) to assess relationship of sighting location and activity of the animals to distance from shore. *G*-tests (Sokal and Rohlf 1995) were used to evaluate differences in activity among the categories.

Information from observational trips also was used to assess distributional changes of *Sotalia* over the day or with tide. Activity and distribution of *Sotalia* in Wauhta lagoon and Pahara inlet during the morning hours (1200 h and before) were compared with those of animals during the afternoon hours (after 1200 h). Number of groups and individuals per hour were calculated based on observations in the morning and afternoon. A *G*-test was used to assess whether activity of the animals at time of sighting differed with time of day in lagoon and inlet areas.

Inferences on tidal affect on the movement of *Sotalia* from the lagoons were drawn from sightings of dolphins entering or leaving the lagoon inlets. Observations were too few to be analyzed statistically.

Other types of data--During this project, other relevant data on interspecific associations, feeding behavior, swimming speed, dive duration, body size, and coloration were opportunistically collected. On a few occasions, *Tursiops truncatus* (bottlenose dolphins) were sighted during the survey and observational trips. Associations of *Sotalia*

and birds were common and were noted.

RESULTS

Surveys

Aerial survey--During 7 h and 10 min of aerial survey time, 21 *Sotalia* were sighted in the Cayos Miskito Reserve (Figs. 2 and 3). On 9 April, *Sotalia* were seen twice (a single individual and a herd of three) in the southern part of the Reserve in Wauhta lagoon. On 10 April, 17 *Sotalia* in two groups (size 2 and 15) were observed in the northern part of the Reserve in Bismuna lagoon. No *Sotalia* were sighted in Karata lagoon, Pahara lagoon, or the coastal areas (Figs. 2 and 3).

Boat surveys and density estimation--During 321 h of survey time (1996, 68 h; 1997, 124 h; 1998, 129 h), 183 groups containing 536 individuals were recorded (1996, 15 groups, 68 *Sotalia*; 1997, 109 groups; 265 *Sotalia*; 1998, 59 groups, 203 *Sotalia*). These totals include repeated sightings of groups and individuals on different days. An appendix in Edwards (1999) provides details for each individual survey.

Sotalia density for all surveys combined was highest in section 8 (Haulover to Wauhta, $\bar{x} = 0.967/km^2$; Table 1, Fig. 4) and no *Sotalia* were sighted in sections 1, 5 and 6 (Pahara lagoon, Karata inlet and Karata lagoon; Table 1, Fig. 4). For the individual years, the two highest densities were in Pahara inlet (section 2) in 1996 ($\bar{x} = 1.39/km^2$) and 1998 ($\bar{x} = 1.10/km^2$). The mean overall density for all sections in which *Sotalia* were sighted (sections 2-4 and 7-10) was $0.593/km^2$. Mean density along the coast (sections 3, 4, 7, 8) was $0.591/km^2$ and in inlet areas (2, 5, 10) was $0.666/km^2$. Wauhta ($\bar{x} =$

0.484/km^2) was the only lagoon in which *Sotalia* were sighted during boat surveys; however, local fishermen reported seeing dolphins in both Karata and Pahara lagoons. We estimate that the combined abundance for all areas surveyed is 48 to 55 individuals; the former value is derived from mean valves of individual sections, while the latter is based on individual values where each individual survey was weighted equally.

Distribution

Nearest-neighbor analysis showed that, during all years, distributions of *Sotalia* sightings were nonrandom, with a tendency towards clumping (1996, $z = -8.56$, $n = 20$, $P < 0.001$; 1997, $z = -21.64$, $n = 128$, $P < 0.001$; 1998, $z = -17.95$, $n = 88$, $P < 0.001$). The nonrandom clumping of sightings indicates, not surprisingly, that *Sotalia* preferentially inhabit given areas of the Reserve.

Time of day--Sightings of *Sotalia* were common in Wauhta lagoon and Pahara inlet. Their occurrence in these areas varied with time of day. In Wauhta lagoon, sightings were as frequent after 1200 h than at 1200 h and before. Between 0530-1200 h *Sotalia* were sighted 14 times during 78 h of surveying (0.18 groups/h, 0.87 individuals/h) and 11 times during 41 h of surveying from 1201-1730 h (0.23 groups/h, 0.85 individuals/h).

In Pahara inlet, sightings were much more frequent in the afternoon from 1201-1630 h than from 0700-1200 h. Between 0700-1200 h, *Sotalia* were sighted six times in

17 h of surveying (0.35 groups/h, 1.1 individuals/h), while they were seen five times in 4.6 h of surveying (1.1 groups/h, 6.5 individuals/h) from 1201-1630 h.

Overall, these results suggest that Wauhta lagoon is used as frequently in the morning and the afternoon hours. Pahara inlet is used more often in the afternoon than in the morning.

Tidal effects on distribution and movement--On five occasions *Sotalia* were sighted traveling out of Pahara inlet to open water. All five observations occurred between 10 and 96 min from the midpoint between high and low tides during the time of slack water (*i.e.*, when current direction changes and its speed is near zero; Anonymous 1995).

At the mouth of Wauhta inlet, *Sotalia* were observed entering 1.5 h after high tide, and, on one occasion, traveling out of Wauhta inlet 1.25 h before low tide. Unlike Pahara inlet, this does not appear to coincide with the time of slack water, but may indicate traveling in or out of Wauhta inlet occurs with the tides. In Wauhta lagoon, *Sotalia* were sighted during all phases of high and low water, and there was no evidence that movements in and out of the lagoon occurred at regular intervals.

Distance from shore--The percentages of sightings recorded for three distance categories for 1997 and 1998 are given in Table 2. During surveys, *Sotalia* were more often sighted 0-100 m from shore (54.0%) and less often from 201-300 m (6.8%; $G = 4.6$, $df = 2$, $P > 0.05$, $n = 161$).

Activity

Time of sighting--The percentages of activities recorded in all areas at time of sighting are given in Table 3. Feeding was the predominant activity observed and was recorded for 70.3% of all sightings. The percentages of activities recorded at the time of sighting in lagoons and inlets are shown in Table 4, and are a subset of the data at the top of Table 3.

Traveling and feeding occurred at similar rates in Wauhta lagoon ($n = 27$), and the two herds of *Sotalia* for which activity were recorded in Wauhta inlet were traveling. Feeding, the predominant activity in Pahara inlet, occurred 83.3% of the time ($n = 13$). Socializing animals were observed engaging in activities of spy-hopping (extending head vertically out of the water; Shane 1990), tail slapping, leaping, breeching, flipping, wave riding, rolling belly up and rubbing against one another. Often the dolphins would engage in rough contact, including chasing one another or slapping with their tails.

Instantaneous sampling--The percentages of time in which *Sotalia* engaged in different activities based on 1,063 records (53 h of instantaneous sampling) are shown at the bottom of Table 3. Feeding was the predominant activity, occurring 56.3% of the time observed. In general, the estimated percentages for different types of activities were similar to those obtained using time-of-sighting data (top of Table 3).

Observations recorded in Wauhta lagoon ($n = 17$, number of records = 220) showed that *Sotalia* engaged in traveling 40.5% of the time, feeding 39.5%, socializing 0.5%, resting 0.9%, and other 18.6%. In Pahara inlet ($n = 7$, number of records = 144), *Sotalia* engaged in traveling 30.6% of the time, feeding 61.8%, resting 0.7%, socializing

0.0%, and other 6.9% (subset of data from bottom of Table 3).

Time of day and distance from shore--The percentages of times engaged in different activities in morning and afternoon hours at time of sighting, for all areas surveyed, (Fig. 5) indicate that *Sotalia* activity did not change significantly throughout daylight hours ($G = 0.049$, df = 2, $P > 0.05$, $n = 236$). Feeding was the predominate activity in both the morning and afternoon, followed by traveling, other, resting and socializing. Also, percentages of time engaged in different activities did not vary with distance from shore (distance categories 0-100 m, 101-200 m, and 201-300 m; $G = 6.92$, df = 4, $n = 149$, $P > 0.05$).

Herd Size

Herd size for 1996-1998 combined ranged from 1-15 individual *Sotalia* ($\bar{x} = 3.1$, SD = 1.8). On average, the largest groups were sighted in Pahara inlet ($\bar{x} = 5.4$, SD = 2.7) and the smallest in section 8 (Haulover to Wauhta, $\bar{x} = 2.3$, SD = 1.4; Table 1). The largest individual group (15 individuals) was sighted in 1996 during the aerial survey of Bismuna lagoon, an area in the northern part of the Reserve not surveyed by boat.

Herd size (adults and calves) varied significantly among years ($F = 11.9$, df = 2 and 238, $P < 0.05$), but did not vary significantly among months ($F = 1.2$, df = 2 and 238, $P > 0.05$). In 1996, herd sizes of 1-12 individuals ($\bar{x} = 4.3$, SD = 2.4) were recorded during 24 sightings involving 102 individual *Sotalia*. On two separate occasions in 1996 the maximum group size of 12 individuals was recorded in section 4 (Puerto Cabezas to Wawa). In 1997, herd size was from 1-8 individuals ($\bar{x} = 2.6$, SD = 1.7) for 134 sightings

involving 352 individual *Sotalia*. In 1998, herds sizes from 1-7 individuals ($\bar{x} = 3.4$, SD = 1.6) were recorded during 82 sightings involving 282 individuals.

Herd sizes did not vary relative to activity of the animals. Mean herd sizes were 2.9 for traveling, 3.0 for feeding, 3.0 for socializing, 3.3 for resting, and 3.5 for other.

During the surveys, 25 calves were recorded in 21 sightings (6 times in 1996, 8 in 1997, and 7 in 1998). Calves were sighted in 4 of the 10 sections: 6 times in section 2 (Pahara inlet), 5 in section 3 (Pier to Pahara), 8 in section 4 (Puerto Cabezas to Wawa), and 2 in section 7 (Wawa to Haulover).

Interspecific Associations

Sotalia frequently were sighted in association with three types of birds: brown pelicans (*Pelecanus occidentalis*), magnificent frigatebirds (*Fregata magnificens*), and terns (predominately royal terns [*Thalasseus maximus*]). Based on data from 1997 and 1998, *Sotalia* were accompanied by birds during 40.5% of sightings (1997, 54.4%, 74 of 136; 1998, 19.8%, 18 of 91). Associations with birds involved magnificent frigatebirds most of the time (87%, $n = 80$), but terns (12%, $n = 11$) and brown pelicans (1%, $n = 1$) also were recorded in close association with *Sotalia*.

Within the Cayos Miskito Reserve, *Tursiops* (referred to by local fisherman as "black dolphins") are regularly seen offshore, particularly in a resource-rich area known as the Miskito Keys. Fisherman reported them to be common in deeper waters, but saw them less often in the inshore areas, where they noted "grey dolphins" (*Sotalia*) to be prevalent. On only nine occasions did we sight *Tursiops* along the coastline. On days in

which numerous groups of *Sotalia* were observed feeding along the shoreline, *Tursiops* were sighted as well. The latter were never recorded in lagoons or seen associating with *Sotalia*. On one occasion, both *Tursiops* and *Sotalia* were feeding within 200 m of one another, yet they were not associating with each other. On another occasion, in which no *Sotalia* were sighted, *Tursiops* were seen feeding on large schools of mackerel (*Scomberomorus* spp.). The mackerel may have been too large for the smaller *Sotalia* to consume, yet attracted the larger *Tursiops* inshore.

Other Observations

Coloration--Pigmentation or coloration varied among the animals in the Reserve and was typical for the species (da Silva and Best 1996). On a number of occasions, we observed animals that were light in color and had a rosy hue on their dorsal side.

Dive duration--Average dive duration for *Sotalia* feeding in lagoon or inlet areas was 40 sec (SD = 28, n = 10). The longest dive time recorded was 90 sec and shortest 11 sec. The shy and illusive nature of *Sotalia* made recording dive duration difficult.

Body size--On 20 April 1997, two adult *Sotalia* carcasses were found washed ashore in section 7 (Haulover to Wauhta) on the beach near the community of Haulover (N13°41', W83°31'). Marks on the animals indicate they became entangled in gill nets, drowned, and were removed and tossed back into the water by fishermen. They were in the same area of the beach and were in a mild state of decomposition, one being a male (length of 1.61 m from tip of rostrum to notch of fluke) and the other a female (length 1.72 m). On 22 April 1997 a carcass was brought in by a fisherman, who caught the

animal in a gill net (Fig. 6). This female had been dead a very short time and had not decomposed (length 1.65 m). All three were adults.

Swimming speed--On one occasion a group of *Sotalia* was observed leaving Wauhta lagoon and inlet just before low tide. With a GPS unit we were able to record their swimming speed by following the animals, traveling parallel to them as they exited the inlet. Their speed varied from 5.83-6.39 m/sec.

DISCUSSION

Density estimate--Accurate density estimates for marine mammals are difficult to obtain. Certain biases occur that can lead to inaccurate counts: sampling may not be random; schools may respond to the survey platform before they are detected; not all schools may be detected; school size may affect probability of sighting; and school-size determination may not be without error (Hammond 1986). The geographical complexity of the Cayos Miskito Reserve, coupled with the local distribution of *Sotalia*, made density estimation particularly challenging.

The very narrow inlets of the Reserve and the inshore shallow-water distribution of *Sotalia* made strip transects the most applicable survey method for these areas. Vidal *et al.* (1997) found that strip transects were better suited than line transects in the Amazon River basin, an environment similar to that encountered in the Reserve. Obtaining coverage of the lagoons was more difficult using strip transects and, consequently, estimates from these areas may be more prone to error. The resulting estimates of *Sotalia* density and population size in the Reserve are considered minimum, given the factors

mentioned above.

Mean overall density estimate for *Sotalia* in the Cayos Miskito Reserve was 0.593/km^2 (Table 1), with the population size in the Reserve area surveyed estimated to be from 48 to 55 individuals. Our estimates are congruent with direct counts of *Sotalia* by Carr and Bonde (1999); they counted a maximum of 63 animals, in lagoons and along the shoreline during aerial surveys in May 1992. However, our overall density estimate is less than those for marine and freshwater *Sotalia* in other parts of its range. For the freshwater form, investigators have reported densities of 0.9/km^2 in the upper Amazon River (Vidal *et al.* 1997) and 1.6/km^2 in the Solimões River, Brazil (Magnusson *et al.*, 1980). Estimates for the marine form are: 5.1/km^2, Baía de Guanabara, Brazil (Geise 1984); 7.6/km^2 for July-October 1984 and 5.7/km^2 for March 1987-January 1988, Baía de Guanabara, Brazil (Geise 1991); and 1.6/km^2, Colombian Caribbean (J. M. Avila, personal communication).

Sotalia density varied geographically from section to section and was highest in the coastal area from Haulover to Wauhta (section 8; 0.967/km^2). This density is similar to that recorded by Vidal *et al.* (1997) for *Sotalia* in the Amazon. The coastal area from Haulover to Wauhta has a sandy bottom, shallow water and steep beaches. *Sotalia* were frequently sighted feeding in front of the community of Haulover on a very steep section of beach. Their frequent use of this shoreline has led to high rates of incidental catch by the local fishermen, who often set gill nets inshore in this area. Haulover and Wauhta have numerous active fisherman; large numbers of fish and shrimp are caught for both subsistence and commercial use. Good feeding conditions, prey abundance and

proximity to the resources in Wauhta lagoon--the only lagoon in which *Sotalia* were sighted--were probably factors contributing to the relatively high numbers of *Sotalia* in this area.

Pahara inlet had the highest density during two of the three years (1996, 1.387/km^2; 1998, 1.101 km^2). These high values are likely related to prey distribution and abundance given that *Sotalia* were feeding most of the time when observed in the inlet.

Identifiable animals with distinguishing marks (*i.e*, cut or nicked dorsal fin) were seen during the surveys on multiple occasions, indicating site fidelity for *Sotalia* within the Reserve. *Sotalia* appear to be locally resident in this area, and large-scale movements or migration do not seem to occur during the dry season.

Habitat use and distribution

Like other cetaceans, *Sotalia* distribution could be influenced by topographical features, water temperature, salinity, water depth, prey distributions, and prey abundance (Au and Perryman 1985, Hni 1985, Vidal *et al.* 1997, Garciá 1998). Vidal *et al.* (1997) judged that high densities of *Sotalia* found in some sections of the Amazon likely were the result of special physiographical and hydrological characteristics, which helped maintain a high abundance of fishes and offered suitable areas for other activities such as resting and reproduction. Garciá (1998) found movements of marine *Sotalia* and *Tursiops* in Bahiá Cispatá, Colombia, to be influenced by season, water temperature, or salinity. Distribution and behavior of marine *Sotalia* in the Cayos Miskito Reserve appear to be influenced by similar environmental variables, although more information is

needed to determine the extent to which these variables affect *Sotalia.*

Bismuna lagoon--The Cayos Miskito Reserve contains four major lagoons and a few smaller, shallower ones (Fig.1). Bismuna, the largest and most northern of the lagoons, supports *Sotalia.* No major source of freshwater empties into it, the water is clear and shallow, fish and shrimp are abundant, and the bottom is muddy with small patches of sea grass (*Halodule*). *Sotalia* were observed in Bismuna lagoon during the aerial survey and may be present there on a regular basis throughout the dry season.

Pahara lagoon and inlet--Pahara is a rocky-bottom lagoon, the second largest in the Reserve. Its southern shores are lined with predominately red and black mangrove, and the northern part of the lagoon is characterized by savanna and pine forest, as well as some mangrove areas. It has no large freshwater source, but does receive drainage from the Slim River. Shrimp are not abundant in Pahara, yet fish are plentiful. This lagoon, like the others, varies in depth with season and tide, but remains shallow most of the year. The inlet leading to the lagoon is lined primarily with red mangrove, the middle is deep, and the inlet becomes very shallow near the mangrove-lined shores (0.5 m). During surveys *Sotalia* were sighted 11 times within this inlet and were almost always feeding when sighted. Often *Sotalia* fed at the junction of the lagoon and inlet in an area where the banks narrow to form the inlet. On several occasions they fed in this region for more than 2 h. When feeding, *Sotalia* often swam near the banks (within 3 m), both with and against the current. At one particular location along the south bank of the inlet/lagoon junction, *Sotalia* repeatedly moved through a turbulent area, with short bursts of speed, apparently in pursuit of prey.

Pahara inlet is a regular feeding area for small groups of *Sotalia*. Inlet feeding was particularly common in the afternoon, during which time socializing and resting were never observed in this area. The lagoon itself appears to be less important than the inlet leading to it. Only on two occasions were *Sotalia* sighted traveling out to the open waters of the lagoon. Local fisherman do not report sighting dolphins in portions of the lagoon farthest from the inlet. The lack of freshwater drainage, the lower percentage of mangrove coverage along shores, and the absence of certain marine species (*i.e.*, shrimp) could account for the low use of this lagoon by *Sotalia*.

Calves were sighted only 25 times in the Reserve, and were most common along the coast (sections 2, 3, and 4). Mothers and calves were sighted more often in or near Pahara inlet than in any other area surveyed. Cows with calves were recorded in the inlet 5 of the 11 times in which *Sotalia* were sighted there. *Sotalia* also were recorded along the beach areas adjacent to the lagoon on five occasions, indicating that the inlet is used on a regular basis. The inlet may provide cows and calves a safe, calm feeding area. However, the relatively few calves seen suggests a low reproductive rate. In fact, casual observations by local inhabitants indicate that *Sotalia* numbers are not being maintained.

Karata lagoon and inlet--Karata lagoon, the smallest of the lagoons, has a muddy bottom interspersed with small patches of sea grass; its shores are lined with red and black mangrove. Although Karata lagoon is directly fed by a major freshwater source, the Wawa River, during certain times of the year much of the lagoon is less than a few meters deep. Sedimentation from logging upstream has become a problem for this lagoon and, in recent years, productivity and water depth have decreased. We sighted no *Sotalia* in

Karata or its tributaries, although locals did report infrequently seeing dolphins in the inlet and lower lagoon. Very shallow water (<0.5 m in some areas), heavy boat traffic, and contamination from the port of Lamlaya and from mining upriver from the Reserve, more than likely contribute to the low number of sightings in this lagoon.

The inlet leading to Karata lagoon, like Pahara inlet, is lined predominately with red mangrove and is deeper than the lagoon itself. This section of the Reserve is very heavily traveled by boats in transit to the port of Lamlaya. Karata lagoon at one time supported many dolphins, and local people have reported that they were seen as far inland as the port of Lamlaya (Lamlaya means "dolphin water" in Miskito) and the Wawa River, which are several kilometers from the mouth of the lagoon.

Wauhta lagoon and inlet--Wauhta, the southernmost of the lagoons, was heavily used by *Sotalia*. It is shallow, has a muddy bottom (no sea-grass beds), and supports an abundant supply of fish and invertebrates, including large numbers of shrimp. The inlet leading to the lagoon, like the others, is narrow and mangrove-lined. Salinities in this lagoon varied with tide and season and, during our study, ranged from 0-33 ‰ ($\bar{x}$ = 18.5 ‰, SD = 8.8, n = 34). They also varied among years, being lowest in the wettest year (1996, $\bar{x}$ = 10.5, SD = 8.7, n = 10) and highest in the driest, El Nīno year (1998, $\bar{x}$ = 23.5 ‰, SD = 3.6, n =13).

Salinity does have seasonal affects on *Sotalia* in parts of its range. In Bahiá de Cispatá, Colombia, they utilize the bay area more often in the dry season, when salinities were highest and fish abundance lowest along coastal regions (Garcia 1998). Salinity per se probably has little direct affect on *Sotalia* distribution during the dry season. However,

it does appear to indirectly influence *Sotalia* by affecting prey distribution. *Sotalia* were observed many times in fresh and brackish water, but most sightings were in the high-saline areas in inlets and along the beaches. Rarely during the dry season did salinities fall below 25 ‰ in the coastal areas, and waters around the lagoon mouths showed only small differences in salinity over coastal waters. Borobia *et al.* (1991) questioned whether freshwater was a physiological necessity for *Sotalia.* This does not seem to be the case for *Sotalia* in the Cayos Miskito Reserve, since truly freshwater (0 ‰) or even low-saline conditions may not be present for months at a time.

Surface-water temperatures in the Reserve ranged from 25° to 32° C and were highest in lagoons and lowest in coastal areas after rains. Temperature changes were usually small and gradual, and seemed to have no affect on *Sotalia* distribution.

The distribution and habitat use of *Sotalia* in the Cayos Miskito Reserve may change during the wet season. In Wauhta lagoon, there is a decrease in the abundance of fish species in the lagoon when salinities are low (Marshall 1996). In the wet season, heavy rains wash many lagoon prey species out to sea, increasing their densities in nearshore areas. The abundance of fish at the mouth of the lagoon inlets and along the shoreline adjacent to the lagoon is said, by local residents, to attract larger marine species, including *Sotalia*, to these areas after heavy rains. Information on *Sotalia* distribution during the wet season is needed to determine whether seasonal changes in distribution occur.

Based on time-of-sighting data in Wauhta lagoon, *Sotalia* were observed traveling (51.9%) more than feeding (40.7%). The percentage of traveling observed in the lagoon

is higher than in other areas and may be a result of movement by the dolphins in response to our boat. *Sotalia* seemed much more affected by our presence in lagoons than in coastal areas. Past encounters with humans and boats in enclosed areas may account for their increased vigilance and subsequent avoidance of our boat. In addition, movement of prey items or shifts in feeding locations may in part account for the higher percentage of traveling observed in this lagoon.

Coastal areas--In coastal areas *Sotalia* prefer feeding in the shallow water along the shoreline. In 1997, 10 herds with a total of 29 individuals were recorded on one day during surveys running south from the pier to the midpoint between Haulover and Wauhta (sections 4, 7 and 8). Factors contributing to higher number of sightings are not known, but calm seas coupled with prey distribution may have been responsible. During rough seas, *Sotalia* are more likely to be at greater distances from shore, which may be related to shifts in prey distribution. Currents also may affect *Sotalia* distribution by directing water from the lagoons, to the shoreline, bringing with it prey items that attract *Sotalia*. While direct measurements were not made, it appears that prey distribution and abundance had the greatest influence on the preference of *Sotalia* for shallow, inshore areas.

Location of topographical and environmental characteristics also may indirectly influence the distribution of *Sotalia* by influencing distribution of prey. A large pier near the town of Puerto Cabezas attracted *Sotalia*. They frequently fed (almost on a daily basis) at the base of the pier. In addition, *Sotalia* were frequently seen feeding in a relatively deep region (*ca.* 5 m) near the beach midway between Haulover and Wauhta

inlet in section 8. Another popular feeding area for *Sotalia* was Braggman's Bluff, the only large cliff-lined, rocky section of the coast in our study area. The cliff extended out from the land, forming a point (section 3; Fig. 2).

Sotalia in the Cayos Miskito Reserve spent a significant proportion of their day feeding. Resource abundance and availability appear to be the greatest factors determining distribution of *Sotalia*. The Reserve's lagoons and rivers form a large estuarian region. Specialization on estuarian species coupled with high energetic needs may attract *Sotalia* to the concentration of resources found in this area. The presence of estuaries, in general, may be necessary to support *Sotalia* populations, and could account for the current northern distribution limits of marine *Sotalia* and may determine distribution throughout its range. Absence of *Sotalia* in parts of Central or South American may be the result of low resource levels brought on by a lack of estuaries and freshwater sources.

Herd size--The mean (3.1) and range (1-15) of herd sizes for *Sotalia* in the Cayos Miskito Reserve were similar to herd sizes recorded elsewhere. Carr and Bonde (1999), in 1992, found herd sizes in the Reserve ranging from 1-20 with a mean of 8.0 ± 6.1. For the freshwater form, Vidal *et al.* (1997) reported an average herd size of 3.9 in the Amazon, and Magnusson *et al.* (1980) noted groups of one to nine in the Rio Solimões of Brazil. In the upper Amazon, Layne (1958) found lone individuals common, and groups larger than four or five rare. For the marine form, A. P. Di Beneditto (personal communication) reported herd sizes of 2-6 with a maximum of 20 individuals in the state of Rio de Janeiro, Brazil, and Geise (1991) found herd sizes of 2-4 in Guanabara Bay,

Brazil. In Bahiá de Cispatá in Colombia, herd sizes of 10 individuals or less were most common (Garcia 1998). However, Bössenecker (1978), P. A. C. Flores (personal communication), and S. M. Simão (personal communication) found very large herd sizes of 50-400 of the marine form common in some coastal areas of South America. South America has some of the world's largest tropical river systems, and much of the continental shelf is estuarine (Longhurst and Pauly 1987). Large estuaries with abundant freshwater sources may support large numbers of animals foraging together. Small and evenly distributed estuaries, like those found in the Cayos Miskito Reserve and other regions of Central America, may account for the smaller more widely dispersed herds seen there.

Interspecific associations--*Sotalia* were associated with birds on numerous occasions (40.5% of all sightings), particularly magnificent frigatebirds. Locating hovering frigatebirds was a good way to find *Sotalia*. The frigatebirds hovered over *Sotalia*, moving with them as they traveled and fed. It appears that frigatebirds actively sought out and followed *Sotalia*, taking advantage of easy prey encountered with feeding dolphins, while terns and brown pelicans were more likely attracted to *Sotalia* after feeding commenced. It did not appear that *Sotalia* used feeding bird flocks as an indicator of feeding by other dolphins, as is the case for dusky dolphins (*Lagenorhynchus obscurus*) in the South Atlantic (Würsig and Würsig 1980).

Body size--Body size of the specimens of *Sotalia* from the Cayos Miskito Reserve is similar to that of the marine form previously collected by Carr and Bonde (1999) in Nicaragua (adult male from the Reserve, length 1.87 m) and parts of South America (1.7

± SD of 0.2 m, $n = 17$ [da Silva and Best 1996]; and largest recorded marine *Sotalia* adults, a male 1.87 m and a female 2.06 m [Barros 1991]). The freshwater form is smaller (1.4 ± SD of 0.2 m, $n = 27$; da Silva 1983, 1994, Best and da Silva 1984, da Silva and Best 1994).

Swimming speed--The swimming speed we recorded (5.9-6.4 m/sec) is similar to those recorded for other small cetaceans (1.1-5.6 m/sec for juvenile *Tursiops* [Lockyer and Morris 1987], 4.5 m/sec for *Delphinus delphis* [Hui 1987], and 6.0 m/sec for *Phocoenoides dalli* [Law and Blake 1994]). Much like the behavior observed for *P. dalli* (Law and Blake 1994), *Sotalia* traveled at high speeds near the surface of the water, surfacing briefly but not leaping clear of the water. Surfacing was accompanied by explosive breathing, and movements through the water produced rooster-tails as the animals swam. The *Sotalia* continued to swim rapidly until out over the shallow-water sand bars of Wauhta inlet. *Sotalia* moved in this manner on other occasions while feeding (chasing fish) and avoiding boats. Most movement by *Sotalia* was slower subsurface travel, accompanied by rolling at the surface.

Coloration--Although pink dorsal coloration has been documented for *Inia geoffrensis* (Trujillo 1994) and pink ventral coloration for other species, such coloration in *Sotalia* have not been described. Changes in ventral coloration are thought to be related to increases in activity. In some species the pink or rosy hue is the result of increased blood supply to the capillaries on the surface of the skin that are used for thermoregulatory purposes (Best and Da Silva 1989). Changes in dorsal coloration of *Sotalia* may result from similar thermoregulatory processes, or possibly from rapid

sloughing of skin due to prolonged exposure to low salinities. In the Reserve, animals with a rosy dorsal hue were most often observed late in the field season (late May or June when rainfall began to increase) when both air and water temperatures were highest and lagoon and coastal salinities were lowest.

Feeding behavior--Sotalia in the Cayos Miskito Reserve spend a significant part of their day feeding along the coastline, in lagoons, or in inlets. Often feeding behavior lasted for hours. Methods of feeding varied among locations and may be influenced by the topography of the area or by the prey species they are pursuing.

As indicated in the Results, *Sotalia* were frequently sighted feeding off a large pier located just outside the urban area of Puerto Cabezas. The area around the pier sustains heavy traffic mainly from lobster, shrimp and fishing boats, which move in and out on a daily basis. It serves as a fishing platform for local people, and small sardines commonly school at the base of the pier. *Sotalia* feed regularly on the south side of the pier, which is protected from predominantly northwesterly winds and remains relatively calm. They swim parallel to the pier, just meters from the docked boats, repeatedly moving out to the end of the pier and pursuing their prey back towards the shore. Sometimes they were observed wave-riding as they approached the beach and followed the fish into very shallow water. In contrast to lagoon areas, noise, boat traffic and pollution did not seem to disturb their feeding activity. Human activities appear to influence *Sotalia* behavior less in open water areas than in the lagoons and inlets. Local people noted that in recent years sightings of *Sotalia* at the pier have declined and herds sizes have decreased.

Sotalia feeding along the beach in other locations often used a similar technique to that employed at the pier. They would move perpendicular to the beach, pursuing prey toward shore. Once reaching the shore they would move parallel to the beach for a short distance before returning to deeper water to pursue prey inshore once again. Their movements usually were slow and steady, although *Sotalia* often wave-rode, leaped or swam with speed in pursuit of small fish. Those engaging in this behavior would remain in tight herds of two to four animals, although they were never seen feeding cooperatively. On a few occasions, *Sotalia* swam in an inverted position as they moved out from shore. Ballance (1992) reported seeing *Tursiops* in the Gulf of California using a similar technique to pursue prey. This inverted position may allow dolphins a better view of the objects they are pursuing, thus providing an advantage while surface feeding. Another possibility is that while feeding in shallow water, the dolphin can echolocate in the inverted position given that its melon would be underwater.

In the lagoon inlets, most of the feeding behavior observed was edge-feeding. The dolphins sighted in the inlet usually moved along the mangrove-lined shore hunting for food, sometimes increasing their speed, in short bursts, to pursue prey. In Pahara inlet in particular, herds of *Sotalia* would spend hours moving up and down the shoreline feeding with or against the current. This method of feeding occurred most frequently near where the lagoon and inlet meet. The tide was going out or there was slack water on all occasions when *Sotalia* were sighted feeding in this area.

Sotalia sometimes moved against the current when feeding where a lagoon narrows to form the inlet. The current is often swifter at the junction and *Sotalia*

appeared to be moving in a feeding rush. They would repeatedly swim through the most turbulent area of the junction and then return to the edge of the shore to continue their pursuit of prey. When feeding they also frequented eddies or calm-water areas adjacent to the junction. Prey probably are concentrated at the lagoon-inlet junction as the lagoon water is pulled into the narrow inlet by the tide. In the Amazon region, feeding behavior of *Sotalia* is most common in turbulent areas of confluences, and *Sotalia* densities are greatest in and around the mouths of streams and canals intersecting the rivers (Magnusson *et al.* 1980, Vidal *et al.* 1997), much like the inlet-lagoon junction in Pahara lagoon.

In Wauhta lagoon *Sotalia* frequently fed in a deep channel that runs through the middle of the southern half of the lagoon. Water movement in the channel is more rapid than in other areas. The dolphins fed by slowly moving up and down the channel, sometimes using short busts of speed to rush their prey. Breeching and leaping often accompanied these bursts. Edge-feeding also was common in the lagoon. On three occasions *Sotalia* were sighted in a very small, shallow lagoon on the east side of the main lagoon. A narrow enclosed area like this may facilitate foraging in some way, or this particular area simply may have a high prey density. During low tides, small fish and invertebrates may wash from the prop roots of mangroves, thus providing plentiful forage for *Sotalia.*

It was not possible to determine the species of prey used by *Sotalia*, but a number of fish and invertebrate species were common in the areas were *Sotalia* fed. Sardines (*Harengula* spp. and *Anchoa* spp.) are particularly common along the beaches and near

the pier. On a number of occasions, when *Sotalia* were observed feeding in association with magnificent frigatebirds, the fish on which the birds were feeding could be identified. Sardines were a common prey choice of the frigatebirds and probably of *Sotalia.* Marshall (1996) conducted a fish survey of Karata, Bismuna and Wauhta lagoons. *Arius* and *Stellifer* were the most abundant fish in the lagoons. During the dry season, yellowfin mojarra (*Gerres cinereus*) were the most abundant fish caught over mud-bottomed areas, while *Penaeus* spp. were more abundant in sea-grass beds. Shrimp caught in sea-grass beds were juveniles, and larger ones were caught near mangrove-lined shores. Crabs (*Callinectes danae* and *Calliectes* spp.) were most abundant in sea grass, and snappers (*Lutjanus analis*) were only caught in sea-grass beds. Several snook species (*Centropomus*) were caught in the dry season and were even more common during the wet season. In general, during the wet season, fewer species were caught in the lagoon, and diversity and abundance of fishes were not greater in areas with fewer sea-grass beds. Marshall (1996) also identified 37 other fish species in the lagoon.

Management and Conservation Implications

Sotalia populations in the Cayos Miskito Reserve appear to be declining. Local people confirm that fewer animals are seen each year. The relatively low density (0.593 individuals/km^2) and apparent low birth rate of *Sotalia* are cause for concern. In the past, it appears that *Sotalia* were found in larger numbers in the area what is now the Cayos Miskito Reserve; some areas of the Reserve are no longer occupied by *Sotalia.* Karata lagoon, Lamlaya and the Wawa River have been pin-pointed as areas that have undergone

substantial declines. Conservation measures are needed to protect areas and resources important to *Sotalia* to insure their survival in the Cayos Miskito Reserve.

Certain areas in the Reserve are used heavily by *Sotalia* and should be protected. *Sotalia* utilized most of the area in the Reserve we surveyed, with the exception of Pahara lagoon, Karata inlet and Karata lagoon. During the dry season, inshore coastal areas (0-200 m off the beach) are the most highly utilized regions. The shallow shoreline area between the communities of Haulover and Wauhta is widely used, Wauhta lagoon and Pahara inlet are preferred feeding areas, and Pahara inlet seems particularly important to cows and calves.

Prey distribution appears to be the largest factor influencing the distribution of *Sotalia* within the Reserve. *Sotalia* spend a very significant portion of their day feeding and, as mentioned above, are found in some areas more often than in others. Prey abundance and availability are critical to maintaining a healthy, stable *Sotalia* population. Recent increases in commercial fishing and rapid human population growth on the Miskito Coast may be negatively affecting the local *Sotalia* population by creating competition and/or depleting resources needed by them. Estuarine regions, like those in the Reserve, are important feeding locations for *Sotalia* and consideration should be given to managing them so as to avoid over exploitation by humans.

Pollution, sedimentation, and habitat loss pose threats to *Sotalia* in the Reserve. Karata lagoon appears to be affected by sedimentation and possible contamination. Increased human usage of the lagoon and inlet may have contributed to its decline in use by *Sotalia*. Other areas also are likely to be affected by similar loss or degradation of

habitat.

Entanglement of cetaceans in gill nets is a widespread problem. Coastal fisheries probably have a greater impact on marine mammals than offshore fisheries because animals along the coasts often have more restricted distributions than oceanic species (Dawson and Slooten 1993). Interviews with local fisherman living within the Reserve indicate that gill-net use is increasing and incidental catch is high. *Sotalia* in the Reserve frequently are found inshore in the same locations where gill nets are regularly set. Knowledge of *Sotalia* habitat preference and use patterns coupled with voluntary limits to fishing may be the most effective way to decrease incidental catch of *Sotalia* in the Cayos Miskito Reserve.

ACKNOWLEDGMENTS

Many people were instrumental in the successful completion of this research. We thank: Richard Cifelli, Victor Hutchison, Frank Sonleitner and Mark Meo for useful comments on this manuscript; the late Stephen Leatherwood, the late Ken Norris, and Keith Mullin for their input on preliminary proposals; Daniel Hough and David Certain of the Oklahoma Biological Survey for providing technical assistance on data analysis and GIS; and Coral McCallister for preparation of figures. We are grateful to Armstrong Wiggins for his assistance in establishing relationships needed for us to work within the Cayos Miskito Reserve. Milton Camacho and Balbo Müeller of the Servicio de Areas Silvestres y Fauna, Ministerio del Ambiente y Recursos Naturales (MARENA) helped us obtain the necessary permits and allowed us use of equipment and supplies. Sergio Chow, Denis Castro, Juan Perez, Jr., Alie Travis and Eydie Proffitte, and many boat

drivers helped with data collection. We also thank Teri Bolton and Marco Villaneuva from the Institute of Marine Sciences, Roatan, Honduras, for help with the aerial survey. The following people and organizations provided financial support of this project: American Indian Graduate Center, American Museum of Natural History, Bryan Crowley, PADI Foundation, Oklahoma Biological Survey, University of Oklahoma Foundation, Graduate College, Graduate Student Senate, and Department of Zoology.

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Table 1. Results of strip-transect surveys for *Sotalia* in the Cayos Miskito Reserve sections 1-10.

Section	Mean herd size	Year									Average density (no./km²)
		1996			1997			1998			
		No. surveys	No. *Sotalia*	Density (no./km²)	No. surveys	No. *Sotalia*	Density (no./km²)	No. surveys	No. *Sotalia*	Density (no./km²)	
1. Pahara lagoon	0.00	3	0	0.000	0	--	--	3	0	0.000	0.000
2. Pahara inlet	5.36	6	17	1.387	10	6	0.294	16	36	1.101	0.903
3. Pier to Pahara	3.04	2	5	0.475	15	43	0.544	19	28	0.280	0.401
4. Puerto Cabezas to Wawa	2.73	5	16	0.640	24	116	0.983	18	43	0.478	0.753
5. Karata inlet	0.00	4	0	0.000	4	0	0.000	11	0	0.000	0.000
6. Karata lagoon	0.00	4	0	0.000	0	--	--	0	--	--	0.000
7. Wawa to Haulover	2.70	2	2	0.150	11	41	0.572	13	37	0.426	0.467
8. Haulover to Wauhta	2.29	0	--	--	6	23	0.999	11	32	0.950	0.967
9. Wauhta lagoon	3.20	11	28	0.542	23	53	0.454	18	23	0.456	0.484
10. Wauhta inlet	3.50	2	0	0.000	11	3	0.257	13	4	0.290	0.253

Table 2. Frequency and percentage (in parentheses) of total sightings of *Sotalia* in coastal areas of the Reserve for distance categories ranging from 0 to 300 m offshore.

	Distance offshore (m)		
Year	0-100	101-200	201-300
1997	45 (48.3)	38 (40.9)	10 (10.8)
1998	42 (61.8)	25 (36.8)	1 (1.5)
Total	87 (54. 0)	63 (39.1)	11 (6.8)

Table 3. Frequency and percentage (in parentheses) of activities of *Sotalia* at time of sighting and during instantaneous sampling in all areas of the Reserve surveyed.

	Activity				
Year	Traveling	Feeding	Socializing	Resting	Other
		Time of sighting			
1996	11 (57.9)	7 (36.8)	0 (0.0)	0 (0.0)	1 (5.3)
1997	19 (15.1)	94 (74.6)	3 (2.4)	1 (0.8)	9 (7.2)
1998	21 (23.1)	65 (71.4)	0 (0.0)	2 (2.2)	3 (3.3)
Total	51 (21.6)	166 (70.3)	3 (1.3)	3 (1.3)	13 (5.5)
		Instantaneous sampling			
1996	17 (23.6)	55 (76.4)	0 (0.0)	0 (0.0)	0 (0.0)
1997	147(31.1)	261(55.3)	48 (10.2)	13 (2.8)	3 (0.6)
1998	164 (31.0)	288 (54.4)	4 (0.8)	12 (2.3)	51 (9.6)
Total	328 (30.6)	604 (56.3)	52 (4.9)	25 (2.3)	54 (5.0)

Table 4. Frequency and percentage (in parentheses) of traveling, feeding and "other" (socializing and resting not observed) by *Sotalia*, recorded at time of sighting in Wauhta lagoon, Wauhta inlet, and Pahara inlet (no sightings recorded in Karata lagoon and inlet, or in Pahara lagoon). Data are subset of those in Table 3.

Location	Traveling	Feeding	Other	Total
Wauhta lagoon	14 (51.9)	11 (40.7)	2 (7.4)	27
Wauhta inlet	2 (100.0)	0 (0.0)	0 (0.0)	2
Pahara inlet	2 (16.7)	10 (83.3)	0 (0.0)	12

FIGURE CAPTIONS

Figure 1. Locator map and *Sotalia* density in sections 1-10 of Cayos Miskito Reserve, Nicaragua.

Figure 2. Sotalia sighting locations in sections 2-4 and 7 in Cayos Miskito Reserve: (A) Pahara inlet; (B) Pier to Pahara inlet; (C) Puerto Cabezas to Wawa; and (D) Wawa to Haulover.

Figure 3. Density of *Sotalia* in sections 8-10 and Bismuna lagoon in Cayos Miskito Reserve: (A) Haulover to Wauhta; (B) Wauhta lagoon; (C) Wauhta inlet; and (D) Bismuna lagoon.

Figure 4. Density of *Sotalia* in sections 1-10 in Cayos Miskito Reserve.

Figure 5. Percentage of activity recorded for *Sotalia* at time of sighting in morning (1200 h and before) and afternoon hours (after 1200 h).

Figure 6. Carcass of female *Sotalia fluviatilis* caught in gill net on 22 April 1997.

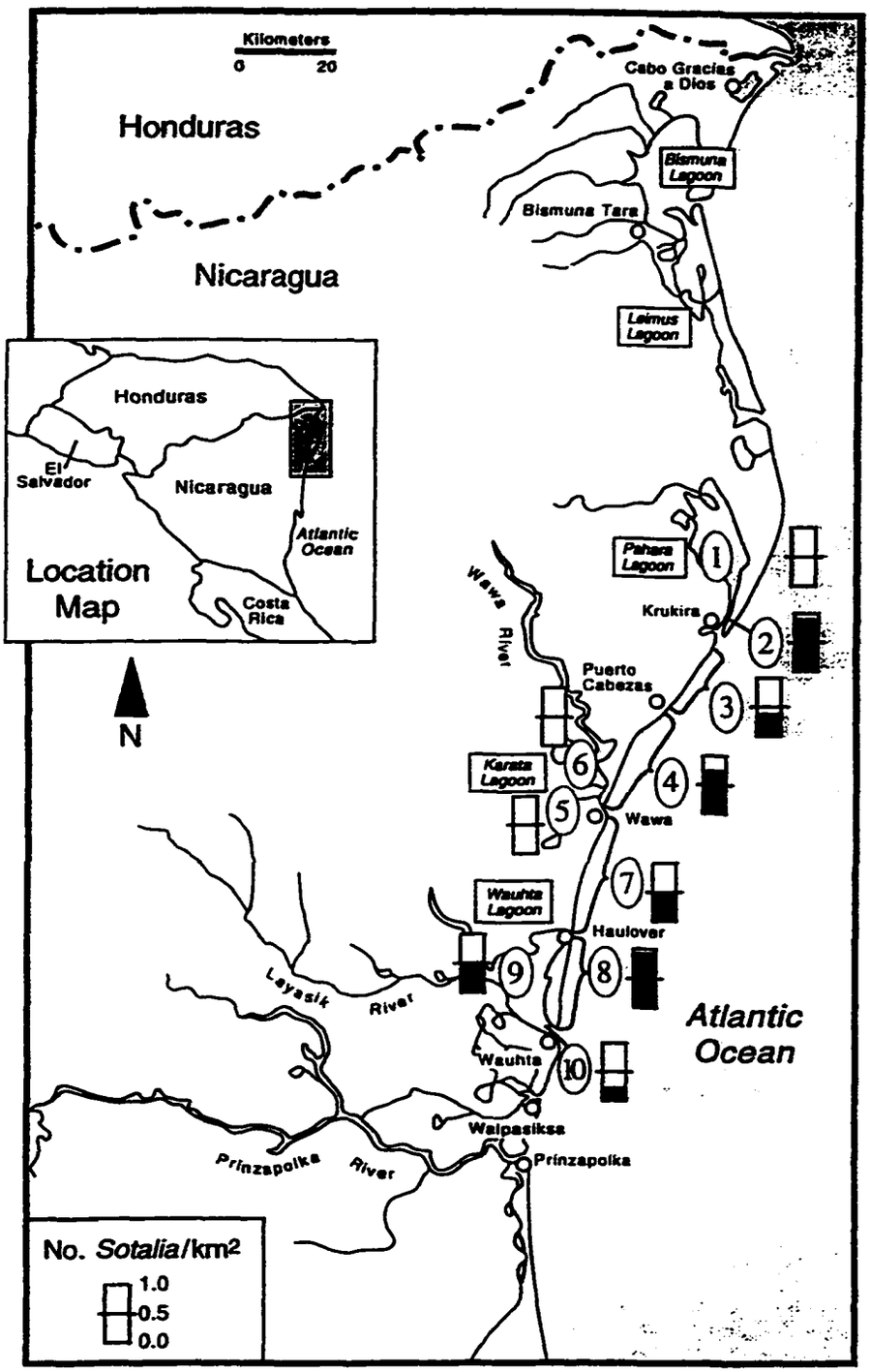

Kilometers
0 20
Honduras
Nicaragua
Cabo Gracias a Dios
Bismuna Lagoon
Bismuna Tara
Leimus Lagoon
Honduras
El Salvador
Nicaragua
Atlantic Ocean
Location Map
Costa Rica
N
Pahara Lagoon
1
Krukira
2
Wawa River
Puerto Cabezas
3
Karata Lagoon
6
4
5
Wawa
7
Wauhta Lagoon
Haulover
9
8
Layasik River
Atlantic Ocean
Wauhta
10
Walpasiksa
Prinzapolka River
Prinzapolka
No. Sotalia/km2
1.0
0.5
0.0

Figure 1.

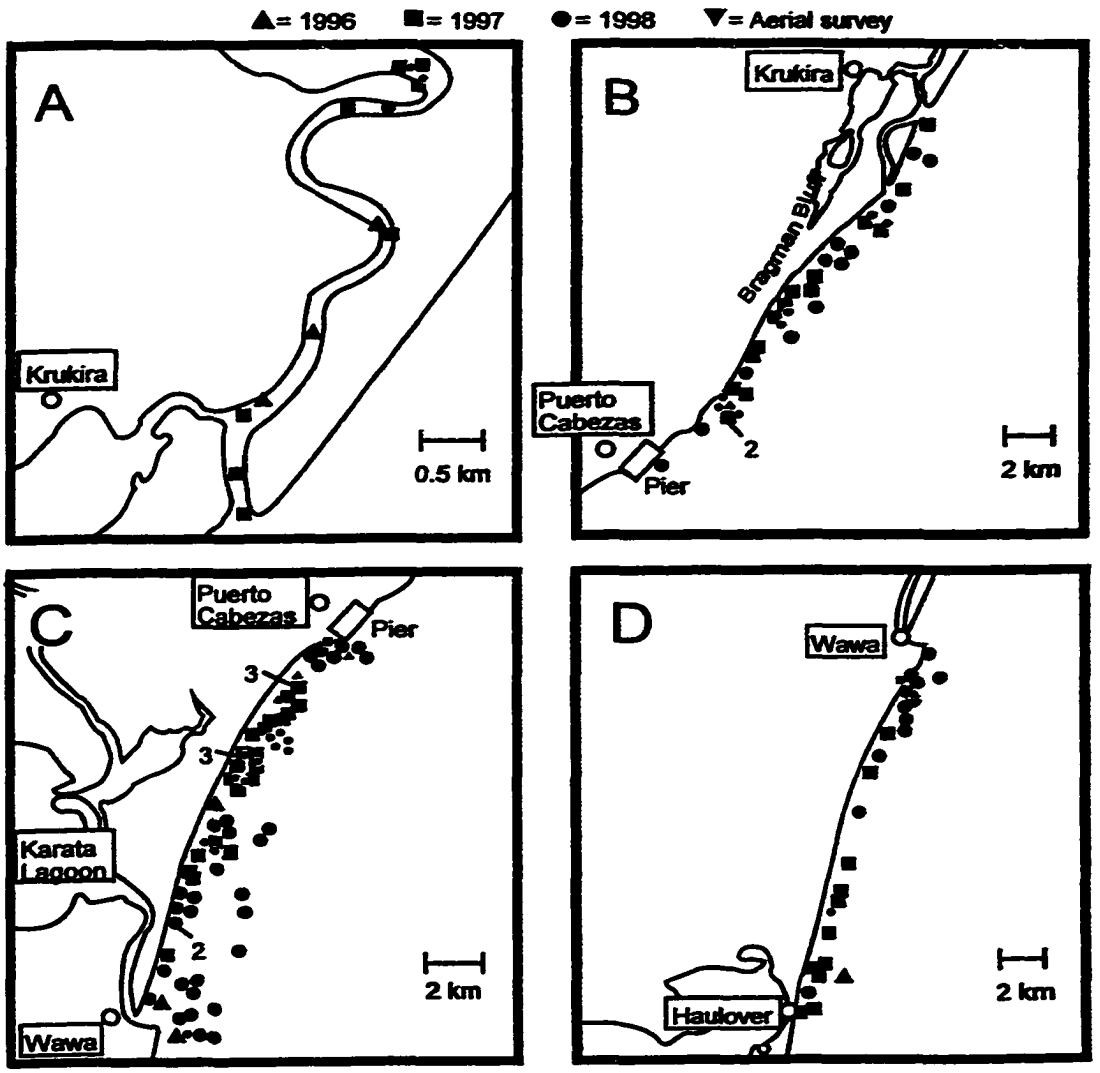

▲= 1996
■= 1997
●= 1998
▼= Aerial survey
A
Krukira
0.5 km
B
Krukira
Bregmen Bluff
Puerto Cabezas
Pier
2
2 km
C
Puerto Cabezas
Pier
3
3
Karata Lagoon
2
Wawa
2 km
D
Wawa
Haulover
2 km

Figure 2.

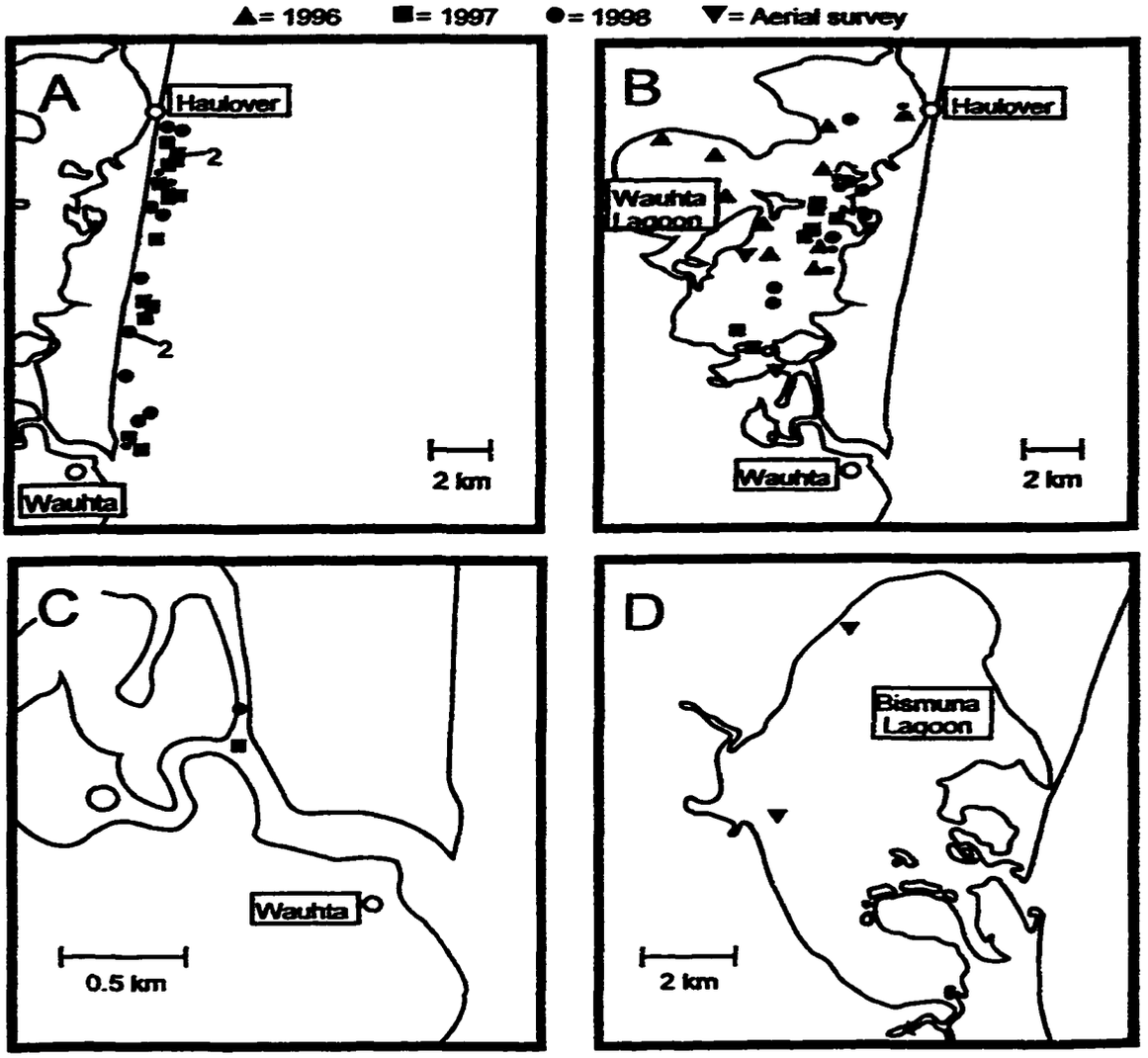

▲= 1996
■= 1997
●= 1998
▼= Aerial survey
A
Haulover
2
2
Wauhta
2 km
B
Haulover
Wauhta Lagoon
Wauhta
2 km
C
Wauhta
0.5 km
D
Bismuna Lagoon
2 km

Figure 3.

Figure 4.

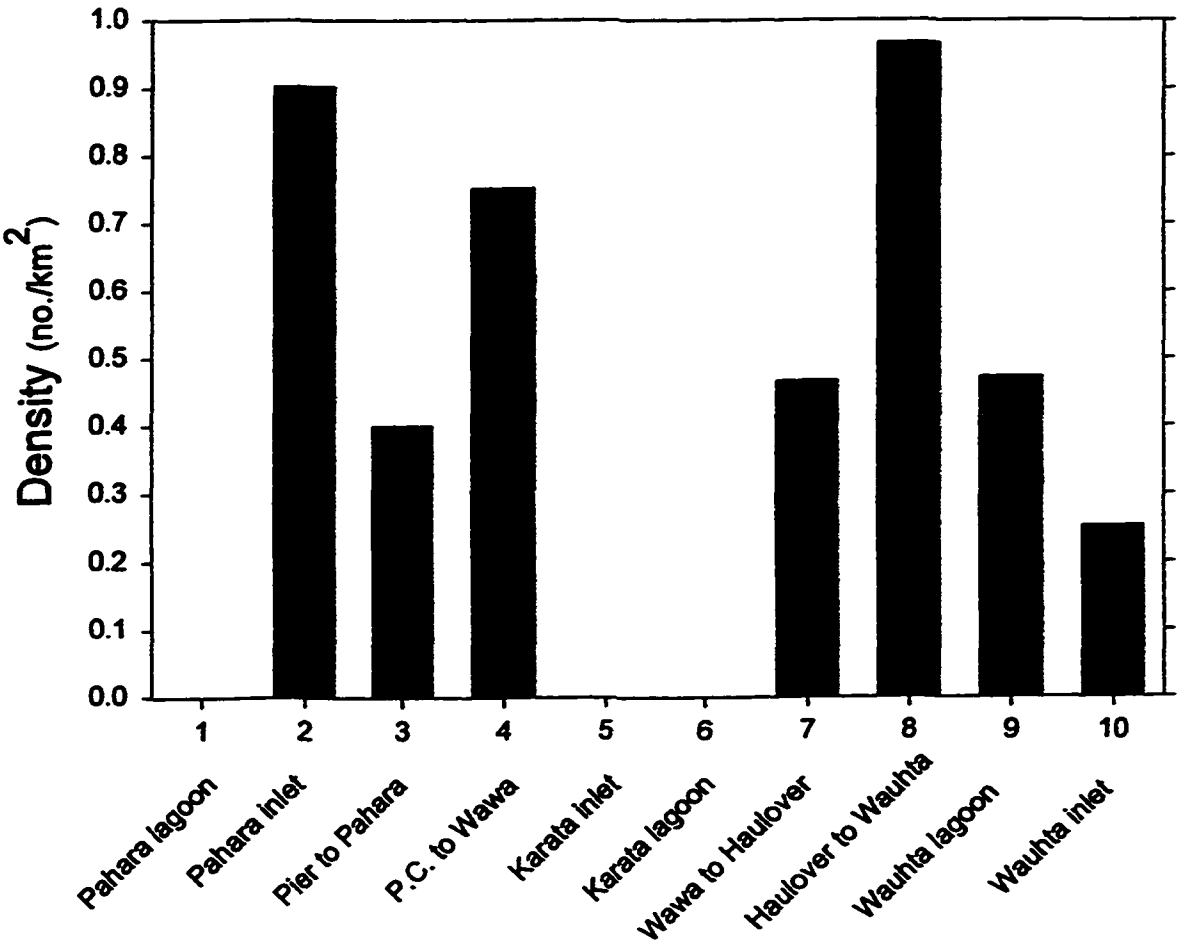
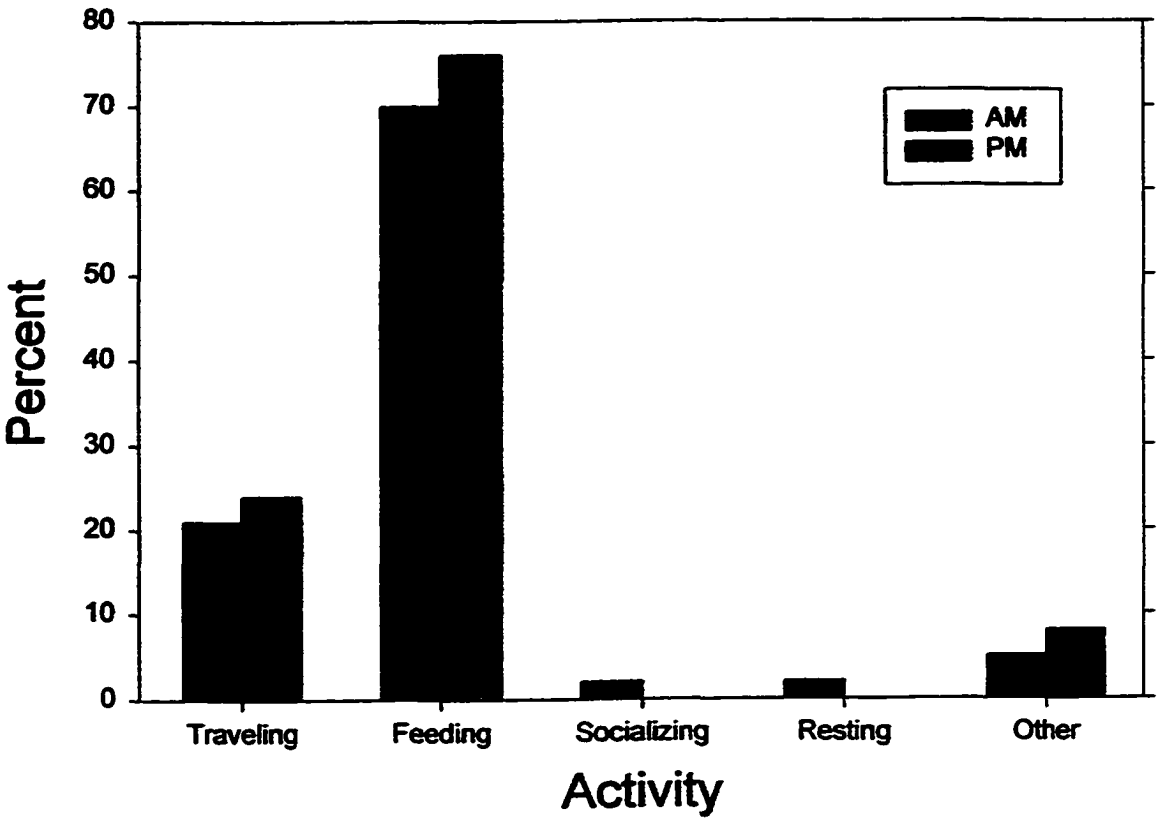

Density (no./km2)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
9
10
Pahara lagoon
Pahara inlet
Pier to Pahara
P.C. to Wawa
Karata inlet
Karata lagoon
Wawa to Haulover
Haulover to Wauhta
Wauhta lagoon
Wauhta inlet

Figure 5.


80
70
60
50
40
30
20
10
0
Percent
AM
PM
Traveling
Feeding
Socializing
Resting
Other
Activity

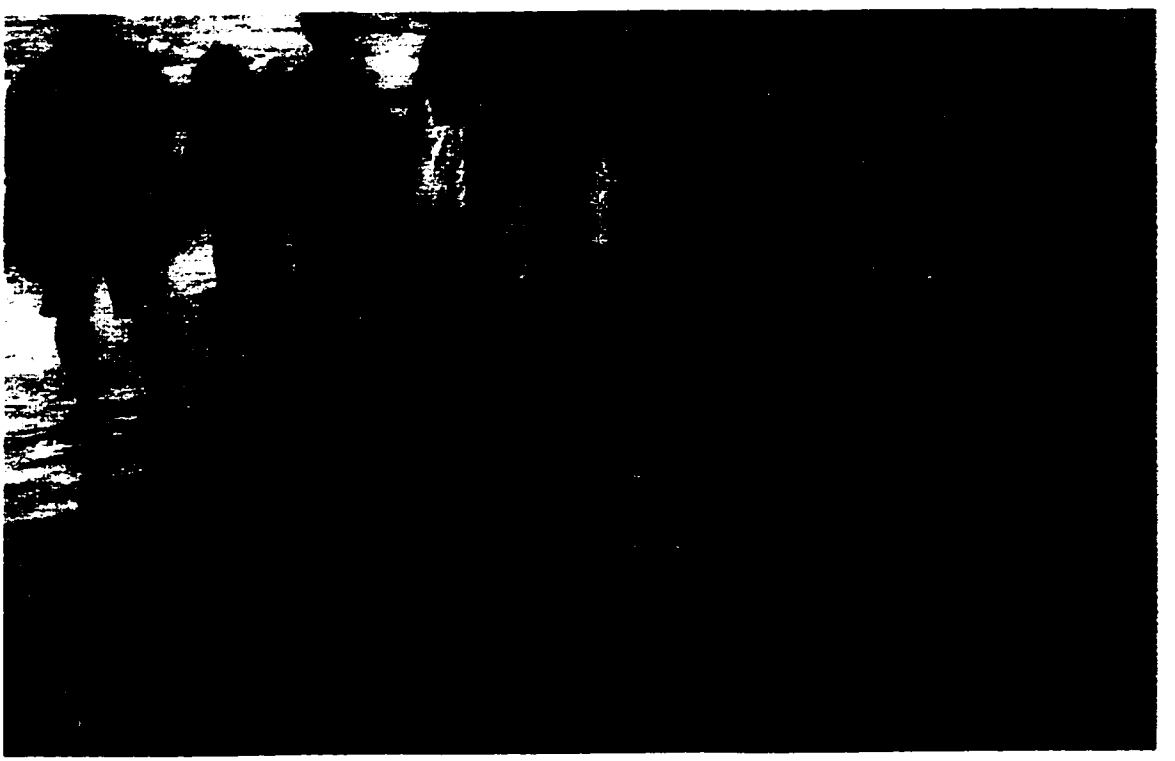


Figure 6.

APPENDIX

RESULTS OF BOAT SURVEYS FOR 1996, 1997 AND 1998

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
		SECTION 1-PAHARA LAGOON				
4/30/96	11:30 am-2:30 pm	0	0	180	5.55	0.00
5/2/96	10:00 am-11:45 pm	0	0	75	9.16	0.00
5/2/96	12:30 am-2:00 pm	0	0	90	3.10	0.00
Total 1996		0	0	345	17.81	0.00
Mean 1996						0.00
3/17/98	9:00 am-12:30 pm	0	0	210	16.89	0.00
3/18/98	9:40 am-12:25 pm	0	0	165	12.05	0.00
3/19/98	9:45 am-11:22 am	0	0	97	6.18	0.00
Total 1998		0	0	472	35.12	0.00
Mean 1998						0.00
Overall mean						0.00
		SECTION 2-PAHARA INLET				
4/30/96	11:00 am-11:30 am	1	6	30	2.04	2.94
5/2/96	9:15 am-10:00 am	0	0	45	2.04	0.00
5/3/96	9:00 am-10:15 am	1	6	75	2.04	2.94
5/4/96	7:50 am-8:30 am	0	0	40	2.04	0.00
5/18/96	9:30 am-9:50 am	1	5	20	2.04	2.45
5/20/96	10:15 am-11:00 am	0	0	45	2.04	0.00
Total 1996		3	17	255	12.26	8.32
Mean 1996						1.39
Overall mean						0.90
3/24/97	8:30 am-9:15 am	0	0	45	2.04	0.00
3/25/97	8:30 am-9:15 am	0	0	45	2.04	0.00
4/1/97	8:15 am-9:00 am	0	0	45	2.04	0.00
4/8/97	9:30 am-10:15 am	0	0	45	2.04	0.00
4/14/97	2:10 pm-2:55 pm	0	0	45	2.04	0.00
4/16/97	10:10 am-10:55 am	0	0	45	2.04	0.00
4/17/97	3:00 pm-3:25 pm	0	0	25	2.04	0.00

Appendix continued

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
4/19/97	1:30 pm-2:15 pm	1	6	45	2.04	2.94
4/28/97	9:30 am-10:15 am	0	0	45	2.04	0.00
5/15/97	8:45 am-10:00 am	0	0	75	2.04	0.00
Total 1997		1	6	460	20.4	2.94
Mean 1997						2.94
3/14/98	9:20 am-10:15 am	0	0	55	2.04	0.00
3/17/98	12:30 pm-12:50 pm	0	0	20	2.04	0.00
3/18/98	8:37 am-9:40 am	1	5	57	2.04	2.45
3/18/98	12:25 pm-12:55 am	0	0	30	2.04	0.00
3/19/98	8:30 am-9:45 am	0	0	75	2.04	0.00
3/19/98	11:22 am-11:53 am	1	4	31	2.04	1.96
3/24/98	1:30 pm-2:09 pm	1	5	39	2.04	2.45
4/2/98	8:40 pm-9:15 am	0	0	35	2.04	0.00
4/8/98	8:42 am- 9:15 am	0	0	33	2.04	0.00
4/11/98	2:35 pm-3:02 pm	1	6	27	2.04	2.94
4/19/98	8:50 am-9:10 am	1	3	20	2.04	1.47
4/28/98	9:15 am-9:50 am	0	0	35	2.04	0.00
4/30/98	9:15 am-10:00 am	0	0	45	2.04	0.00
5/1/98	1:35 pm-2:00 pm	1	7	25	2.04	3.43
5/9/98	12:05 pm-12:25 pm	0	0	20	2.04	0.0
5/11/98	1:30 pm-2:00 pm	1	6	30	2.04	2.94
Total 1998		7	36	577	32.69	17.62
Mean 1998						1.10
Overall mean						0.93
		SECTION 3-PIER TO PAHARA				
5/18/96	8:30 am-9:30 am	0	0	60	5.27	0.00
5/20/96	8:00 am-9:00 am	1	5	60	5.27	0.95
Total 1996			5	120	0.95	0.95
Mean 1996					0.47	0.47
3/24/97	7:00 am-8:30 am	0	0	90	5.27	0.00
3/25/97	7:30 am-8:30 am	0	0	60	5.27	0.00
3/29/97	6:15 am-7:30 am	2	3	75	5.27	0.57
4/1/97	7:10 am-8:15 am	2	3	70	5.27	0.57

Appendix continued

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
4/8/97	6:55 am-9:15 am	3	8	140	5.27	1.52
4/14/97	12:20 pm-2:10 pm	2	4	100	5.27	0.76
4/16/97	7:50 am-10:10 am	1	1	140	5.27	0.19
4/17/97	12:15 pm-2:15 pm	1	3	120	5.27	0.57
4/19/97	12:30 pm-1:30 pm	0	0	60	5.27	0.00
4/28/97	8:00 am-9:30 am	0	0	90	5.27	0.00
5/7/97	6:20 am-8:20 am	3	7	120	5.27	1.33
5/8/97	11:40 am-1:00 pm	2	8	80	5.27	1.52
5/14/97	11:15 am-12:00 pm	0	0	45	5.27	0.00
5/15/97	11:15 am--12:15 pm	1	6	60	5.27	1.14
5/2/97	8:00 am-9:00 am	0	0	60	5.27	0.00
Total 1997		17	43	1310	79.01	8.16
Mean 1997						0.54
3/10/98	7:20 am-9:30 am	1	2	130	5.27	0.33
3/14/98	7:25 am-9:20 am	2	10	125	5.27	1.65
3/17/98	7:00 am-8:15 am	0	0	75	5.27	0.00
3/17/98	12:50 pm-1:45 pm	0	0	55	5.27	0.00
3/18/98	7:25 am-8:37 am	0	0	72	5.27	0.00
3/18/98	12:55 pm-1:55 pm	0	0	60	5.27	0.00
3/19/98	7:25 am-8:30 am	0	0	65	5.27	0.00
3/19/98	12:13 pm-1:25 pm	0	0	72	5.27	0.00
3/23/98	12:30 pm-2:00 pm	1	5	90	5.27	0.83
3/24/98	12:10 pm-1:30 pm	0	0	80	5.27	0.00
4/1/98	7:10 am-8:40 am	1	3	90	5.27	0.49
4/8/98	7:25 am-8:42 am	0	0	137	5.27	0.00
4/11/98	1:25 pm-2:35 pm	0	0	70	5.27	0.00
4/19/98	7:30 am-8:50 am	1	2	80	5.27	0.33
4/28/98	8:00 am-9:15 am	0	0	75	5.27	0.00
4/30/98	7:45 am-9:15 am	1	5	90	5.27	0.82
5/1/98	12:20 pm-1:35 pm	0	0	75	5.27	0.0
5/9/98	10:35 am-11:55 am	1	1	80	5.27	0.17
5/11/98	12:30 am-1:30 pm	0	0	60	5.27	0.0
Total 1998		8	28	1581	100.08	4.62
Mean 1998						0.28
Overall mean						0.40

Appendix continued

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
4/11/96	8:15 am-9:15 am	1	4	60	5.00	0.80
4/19/96	11:30 am-1:15 pm	1	12	105	5.00	2.40
5/15/96	6:50 am-8:30 am	0	0	100	5.00	0.00
5/27/96	11:45 am-1:45 pm	0	0	120	5.00	0.00
Total 1996		2	16	440	25.01	3.20
Mean 1996						0.64
3/20/97	11:45 am-12:50 pm	1	6	65	5.00	1.20
3/21/97	10:30 am-12:00 pm	1	1	90	5.00	0.20
3/22/97	11:30 am-2:00 pm	1	8	90	5.00	1.60
3/29/97	11:15 am-1:00 pm	3	4	105	5.00	0.80
3/31/97	12:00 pm-1:30 pm	2	6	90	5.00	1.20
4/8/97	6:45 am-6:55 am	1	1	10	5.00	0.20
4/9/97	7:30 am-9:15 am	2	4	105	5.00	0.80
4/9/97	10:45 am-10:55 pm	1	3	10	5.00	0.60
4/15/97	8:15 am-9:45 am	3	7	90	5.00	1.40
4/15/97	10:30 am-10:40 am	1	2	10	5.00	0.40
4/16/97	1:00 pm-1:30 pm	0	0	30	5.00	0.00
4/17/97	9:20 am-11:15 am	2	5	115	5.00	1.00
4/18/97	8:20 am-10:00 am	4	12	100	5.00	2.40
4/21/97	7:55 am-9:30 am	3	7	95	5.00	1.40
4/30/97	8:05 am-11:25 am	5	12	200	5.00	2.40
5/2/97	7:45 am-8:00 am	1	2	15	5.00	0.40
5/3/97	8:20 am-10:15 am	5	6	115	5.00	1.20
5/5/97	7:30 am-7:40 am	1	1	10	5.00	0.20
5/5/97	9:00 am-9:45 am	1	8	45	5.00	1.60
5/9/97	9:00 am-9:45 am	0	0	45	5.00	0.00
5/15/97	6:30 am-6:45 am	1	6	15	5.00	1.20
5/16/97	7:50 am-9:30 am	4	6	100	5.00	1.20
5/19/97	2:15- pm-4:15 pm	2	5	120	5.00	1.00
5/20/97	8:00 am-11:45 am	3	6	225	5.00	1.20
Total 1997		48	118	1895	120.04	23.59
Mean 1997						0.98
3/14/98	11:30 am-12:30 pm	0	0	30	2.41	0.00
3/15/98	7:15 am-8:45 am	3	8	90	5.00	1.60
3/21/98	8:09 am-9:12 am	0	0	62	5.00	0.00

Appendix continued

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
3/21/98	12:25 pm-1:30 pm	1	2	55	5.00	0.40
3/22/98	7:20 am-8:16 am	0	0	56	5.00	0.00
3/22/98	12:30 pm-1:25 pm	0	0	55	5.00	0.00
3/27/98	12:15 pm-1:30 pm	0	0	75	5.00	0.00
4/1/98	7:10 am-9:15 am	1	6	125	5.00	1.20
4/2/98	12:00 pm-1:20 pm	1	4	80	5.00	0.80
4/18/98	7:20 am-8:40 am	0	0	100	5.00	0.0
4/20/98	7:15 am-8:40 am	0	0	85	5.00	0.0
4/27/98	11:20 am-12:43 pm	2	5	83	5.00	1.00
4/28/98	10:45 am-12:00 pm	2	7	75	5.00	1.40
4/29/98	8:00 am-9:15 am	1	2	75	5.00	0.40
5/2/98	12:20 pm-1:35 pm	0	0	75	5.00	0.00
5/9/98	7:30 am-9:00pm	0	0	90	5.00	0.00
5/12/98	7:15 am-8:30 am	2	9	75	5.00	1.80
Total 1998		13	43	1376	87.44	8.60
Mean 1998						0.48
Overall mean						0.75
		SECTION 5-KARATA INLET				
4/16/96	1:45 am-2:50 pm	0	0	65	2.25	0.00
4/17/96	1:15 am-2:05 pm	0	0	50	2.25	0.00
4/20/96	8:40 am-9:20 am	0	0	60	2.25	0.00
5/15/96	9:00 am-10:00 am	0	0	60	2.25	0.00
Total 1996		0	0	235	9.01	0.00
Mean 1996						0.00
3/20/97	8:00 am-8:30 am	0	0	30	2.25	0.00
3/21/97	7:30 am-8:00 am	0	0	30	2.25	0.00
3/22/97	7:15 am-7:45 am	0	0	30	2.25	0.00
4/3/97	9:15 am-9:45 am	0	0	30	2.25	0.00
Total 1997		0	0	120	9.01	0.00
Mean 1997						0.00
3/21/98	9:12 am-9:52 am	0	0	40	2.25	0.00
3/22/98	12:05 pm-12:30 pm	0	0	25	2.25	0.00
3/28/98	9:55 am-10:20 am	0	0	25	2.25	0.00
4/1/98	9:15 am-9:40 am	0	0	35	2.25	0.00

Appendix continued

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
4/11/98	9:30 am-10:00 am	0	0	30	2.25	0.00
4/20/98	9:30 am-10:00 am	0	0	30	2.25	0.00
4/22/98	9:30 am-9:45 am	0	0	15	2.25	0.00
5/4/98	9:30 am-9:50 am	0	0	20	2.25	0.00
5/6/98	11:45 am-12:05 pm	0	0	20	2.25	0.00
5/9/98	9:00 am-9:40 am	0	0	40	2.25	0.00
5/12/98	8:30 am-8:50 am	0	0	20	2.25	0.00
Total 1998		0	0	300	24.79	0.00
Mean 1998						0.00
Overall mean						0.00
	SECTION 6-KARATA LAGOON					
4/16/96	7:12 am-12:32 pm	0	0	320	10.81	0.00
4/17/96	7:45 am-12:30 pm	0	0	285	10.11	0.00
4/19/96	7:00 am-9:20 am	0	0	140	7.29	0.00
4/19/96	12:50 am-1:40 pm	0	0	50	2.60	0.00
Total 1996		1	1	795	30.80	0.00
Mean 1996						0.00
Overall mean						0.00
	SECTION 7-WAWA TO HAULOVER					
5/15/96	8:30 am-9:00 am	0	0	30	6.68	0.0
5/24/96	10:30 am-11:30 am	1	2	60	6.68	0.30
Total 1996		1	2	90	13.35	0.30
Mean 1996						0.15
3/21/97	9:30 am-10:00 am	1	2	15	6.68	0.30
3/22/97	7:45 am-8:15 am	1	3	30	6.68	0.45
4/3/97	9:45 am-11:30 am	0	0	105	6.68	0.00
4/5/97	2:15 pm-3:15 pm	0	0	120	6.68	0.00
4/10/97	8:50 am-11:00 am	1	2	90	6.68	0.30
4/18/97	10:00 am-1:00 pm	4	13	120	6.68	1.95
4/21/97	9:30 am-10:30am	2	4	60	6.68	0.60
5/3/97	10:15 am-10:45 am	3	7	30	6.68	1.05
5/9/97	9:45 am-11:15 am	2	3	90	6.68	0.45
5/11/97	10:45 am-12:00 pm	1	4	75	6.68	0.60

Appendix continued

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
5/16/97	9:30 am-11:15 am	2	4	105	6.68	0.60
Total 1997		17	42	840	73.45	6.29
Mean 1997						0.57
3/11/98	8:30 am-10:00 am	1	1	90	6.67	0.15
3/21/98	9:52 am-10:40am	3	11	108	6.67	1.65
3/22/98	8:16 am-9:45 am	2	5	89	6.67	0.75
3/28/98	10:30 am-11:45 am	0	0	75	6.67	0.00
3/30/98	11:20 am-1:00 pm	1	4	100	6.67	0.60
3/30/98	1:35 pm-1:50 pm	0	0	15	6.67	0.00
4/13/98	10:00 am-11:30 am	2	7	90	6.67	1.05
4/18/98	8:40 am-10:11 am	0	0	91	6.67	0.00
4/22/98	9:45 am-11:10 am	0	0	85	6.67	0.00
4/29/98	9:15 am-10:40 am	1	2	85	6.67	0.30
5/4/98	9:50 am-11:30 am	1	4	90	6.67	0.60
5/6/98	10:13 am-11:45 am	1	3	92	6.67	0.45
5/12/98	9:00 am-10:15 am	0	0	75	6.67	0.00
Total 1998		12	37	1085	86.80	5.54
Mean 1998						0.43
Overall mean						0.467
	SECETION 8-HAULOVER COMMUNITY TO WAUHTA					
4/18/97	1:00 pm-1:55 pm	2	4	55	2.25	1.78
4/21/97	1:30 pm-2:45 pm	1	2	75	4.50	0.44
4/23/97	8:20 am-10:10 am	4	6	110	4.50	1.33
5/10/97	6:50 am-7:50 am	0	0	60	4.50	0.00
5/11/97	8:50 am-10:15 am	4	9	80	4.50	2.00
5/16/97	11:15 am-12:30 pm	1	2	75	4.50	0.44
Total 1997		12	23	455	24.78	6.00
Mean 1997						1.00
3/22/98	9:45 am-10:56 am	2	5	71	2.23	2.240
3/28/98	12:15 pm-1:30 pm	2	6	75	4.50	1.330
3/30/98	9:30 am-10:50 am	1	2	80	4.50	0.44
4/13/98	11:50 am-12:50 pm	0	0	60	4.50	0.00
4/15/98	9:48 am-11:00 am	1	1	72	4.50	0.22

Appendix continued

Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
4/18/98	10:11 am-11:07 am	0	0	56	4.50	0.00
4/22/98	11:25 am-12:30 pm	1	2	55	4.50	0.44
4/28/98	10:48 am-11:40 am	0	0	52	4.50	0.00
5/4/98	12:00 pm-1:13 pm	1	2	73	4.50	0.44
5/6/98	8:20 am-9:50 am	2	11	90	4.50	2.44
5/12/98	10:15 am-10:40 am	2	3	25	1.04	2.87
Total 1998		12	32	709	43.81	10.45
Mean 1998						0.95
Overall mean						0.97
		SECTION 9-HAULOVER LAGOON				
4/11/96	1:30 pm-4:10 pm	1	4	160	4.46	0.90
4/12/96	6:00 am-8:10 am	1	3	130	5.34	0.56
4/23/96	11:45 am-12:45	0	0	60	2.18	0.00
4/23/96	1:15 pm-3:30 pm	1	4	135	4.49	0.89
4/24/96	6:15 am-11:45 pm	2	7	330	9.35	0.75
4/25/96	7:15 am-10:30 am	0	0	195	8.43	0.00
5/22/96	12:25 pm-1:25 pm	1	4	145	6.48	0.62
5/23/96	6:37 am-8:45 am	1	4	128	5.33	0.75
5/23/96	1:45 pm-3:45 pm	0	0	120	5.35	0.00
5/24/96	6:25 am-9:00 am	1	2	155	6.16	0.32
Total 1996		8	28	1558	57.58	5.96
Mean 1996						0.54
4/3/97	1:52 pm-4:25 pm	1	4	145	5.33	0.75
4/4/97	7:30 am-11:06 am	0	0	216	7.35	0.00
4/4/97	1:50 pm-4:45 pm	1	4	175	6.23	0.64
4/5/97	6:53 am-12:00 pm	1	2	307	11.16	0.18
4/10/97	2:00 pm-3:00 pm	0	0	60	2.86	0.00
4/10/97	3:40 pm-4:30 pm	0	0	50	1.07	0.00
4/11/97	6:54 am-7:50 am	0	0	56	2.24	0.00
4/11/97	8:50 am-11:20 am	0	0	150	5.28	0.00
4/11/97	2:11 pm-3:30 pm	0	0	124	4.32	0.00
4/11/07	4:15 pm-5:00 pm	0	0	45	2.02	0.00
4/12/97	6:08 am-6:50 am	0	0	42	1.91	0.00
4/12/97	7:20 am-7:40 am	1	6	20	0.79	7.57
4/21/97	3:15 pm-4:30 pm	0	0	75	6.73	0.00

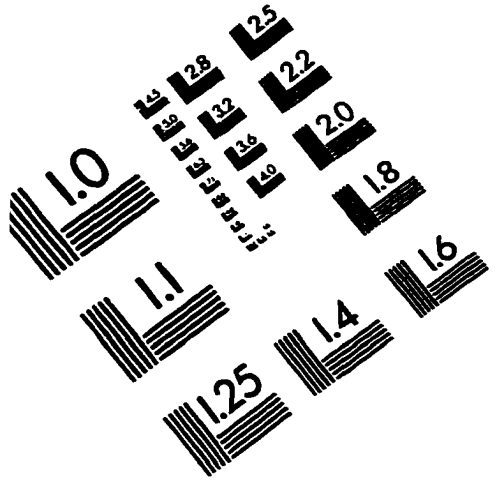
Appendix continued

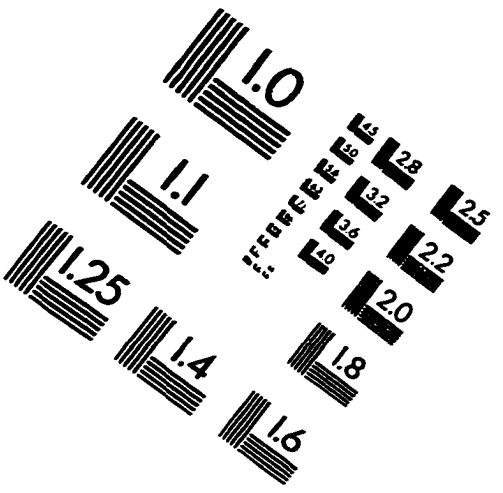
Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
4/22/97	7:55 am-8:30 am	1	5	35	8.65	0.58
4/22/97	1:30 pm-2:30 pm	0	0	60	3.36	0.00
4/22/97	3:00 pm-4:30 pm	0	0	90	4.12	0.00
4/23/97	7:15 am-8:00 am	0	0	45	6.84	0.00
5/9/97	1:20 pm-2:15 pm	0	0	55	3.89	0.00
5/9/97	2:45 pm-3:05 pm	1	4	20	3.89	1.03
5/10/97	8:10 am-11:30 am	1	5	200	14.68	0.34
5/10/97	3:20 pm-4:20 pm	0	0	60	3.69	0.00
5/10/97	4:50 pm-5:30 pm	0	0	40	3.46	0.00
5/11/97	7:00 am-8:30 am	0	0	90	6.02	0.00
Total 1997		13	30	2115	115.88	10.44
Mean 1997						0.45
3/29/98	7:20 am-12:45 pm	1	4	325	13.59	0.29
3/29/98	2:30 pm-3:40 pm	1	2	70	2.96	0.68
3/30/98	6:37 am-8:10 am	1	5	93	2.50	2.00
4/13/98	1:10 pm-3:00 pm	0	0	110	3.55	0.00
4/14/98	7:05 am-8:08 am	0	0	63	3.96	0.00
4/14/98	8:55 am-10:54 am	2	6	131	2.29	2.62
4/15/98	7:07 am-9:35 am	0	0	148	7.19	0.00
4/22/98	12:55 pm-3:15 pm	0	0	140	5.75	0.00
4/23/98	7:00 am-8:55 am	0	0	115	5.75	0.00
4/23/98	10:00 am-11:40 am	0	0	100	3.81	0.00
4/23/98	2:00 pm-2:55 pm	0	0	115	2.34	0.00
4/23/98	3:45 pm-4:45 pm	0	0	60	2.42	0.00
4/24/98	6:00 am-6:45 am	0	0	45	1.93	0.00
5/4/98	1:30 pm-4:00 pm	0	0	150	5.84	0.00
5/5/98	6:50 am-10:45 am	1	6	205	2.23	2.61
5/5/98	1:30 pm-2:30 pm	0	0	60	4.65	0.00
5/5/98	3:10 pm-4:30 pm	0	0	80	2.43	0.00
5/6/98	6:00 am-7:35 am	0	0	95	4.40	0.00
Total 1998		6	23	2045	75.23	8.21
Mean 1998						0.46
Overall mean						0.47
		SECECTION 10-WAUHTA INLET				
4/23/96	12:45 pm-1:05 pm	0	0	20	1.06	0.00

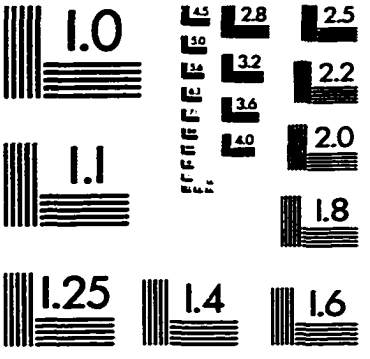
Appendix continued

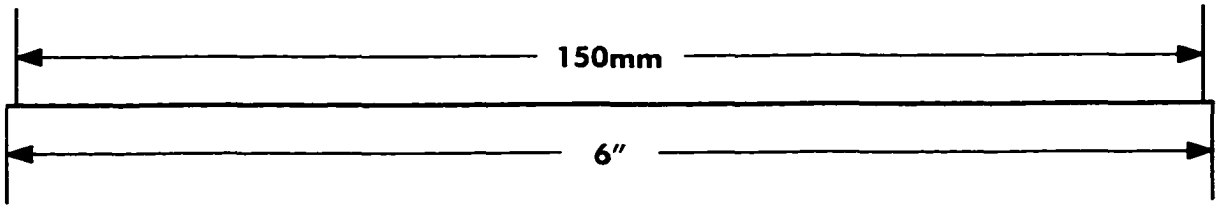
Date	Survey time	No. sightings	Total no. animals	Total time (min)	Area covered (km^2)	Density (no./km^2)
5/22/96	1:25 pm-1:55 pm	0	0	20	1.06	0.00
Total 1996		0	0	40	2.13	0.00
Mean 1996						0.00
4/5/97	10:00 am-10:30 am	0	0	20	1.06	0.00
4/10/97	3:00 pm-3:20 pm	0	0	20	1.06	0.00
4/11/97	7:50 am-8:30 am	1	3	50	1.06	2.82
4/12/97	6:50 am-7:10 am	0	0	20	1.06	0.00
4/21/97	2:45 pm-3:15 pm	0	0	30	1.06	0.00
4/22/97	2:30 pm-2:50 pm	0	0	20	1.06	0.00
4/23/97	8:00 am-8:20 am	0	0	20	1.06	0.00
5/9/97	2:15 pm-2:35 pm	0	0	20	1.06	0.00
5/10/97	7:50 am-8:10 am	0	0	20	1.06	0.00
5/10/97	4:20 pm-4:40 pm	0	0	20	1.06	0.00
5/11/97	8:30 am-8:50 am	0	0	20	1.06	0.00
Total 1997		1	3	240	11.69	2.82
Mean 1997						0.26
3/21/98	1:30 pm-2:25 pm	1	4	55	1.06	3.76
3/29/98	3:40 pm-4:00 pm	0	0	20	1.06	0.00
3/30/98	7:50 am-8:10 am	0	0	20	1.06	0.00
4/13/98	12:50 pm-1:10 pm	0	0	20	1.06	0.00
4/14/98	8:08 am-8:25 am	0	0	17	1.06	0.00
4/15/98	9:35 am-9:48 am	0	0	18	1.06	0.00
4/22/98	12:30 pm-12:55 pm	0	0	25	1.06	0.00
4/23/98	8:55 am-9:15 am	0	0	20	1.06	0.00
4/23/98	2:55 pm-3:15 pm	0	0	20	1.06	0.00
4/24/98	6:45 am-6:55 pm	0	0	10	1.06	0.00
5/4/98	1:13 pm-1:30 pm	0	0	17	1.06	0.00
5/5/98	2:30 pm-2:50 pm	0	0	20	1.06	0.00
5/6/98	7:35 am-8:20 am	0	0	45	1.06	0.00
Total 1998		1	4	307	13.81	3.76
Mean 1998						0.29
Overall mean						0.25

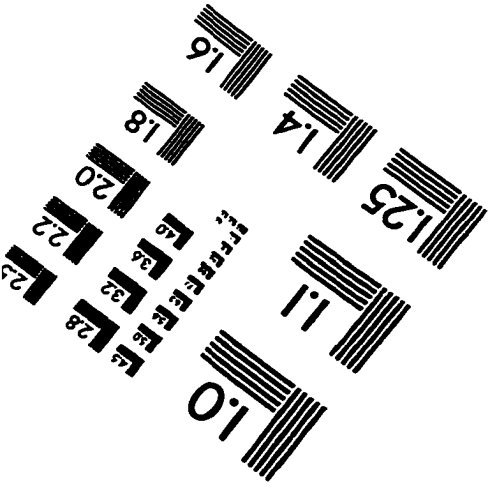
IMAGE EVALUATION
TEST TARGET (QA-3)

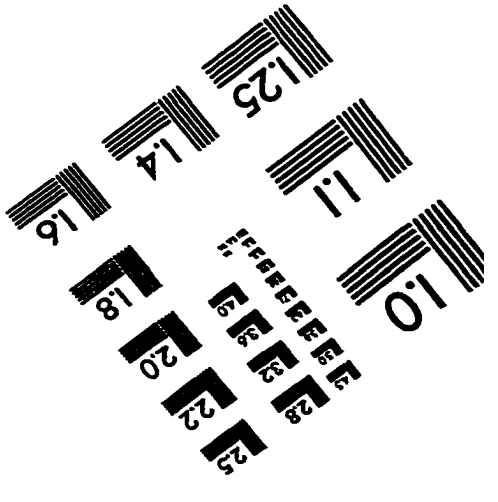












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