I. INTRODUCTION

Florida manatees, *Trichechus manatus latirostris*, are endangered, and many animals are killed or injured each year by boat strikes. At least 25% of annual documented manatee deaths are due to collisions with vessels (Marine Mammal Commission, 2002). Despite the fact that behavioral evidence indicates that manatees do have the ability to detect and respond to approaching vessels (Nowacek et al., 2000; Weigle et al., 1994), the animals continue to be hit. In an effort to contribute to solutions that might reduce manatee morbidity and mortality from boat strikes, we set out to build a device to alert boaters of the presence of manatee vocalizations.

Vocalizations may be the most easily detected sounds produced by manatees (compared to chewing and flatulence) because published reports show them to have the highest signal-to-noise ratio and the vocalizations occur in frequency bands most dissimilar to the natural background noise of the manatees’ environment. To determine the amount of stereotypy in vocalizations we recorded sounds from Antillean manatees (*Trichechus manatus manatus*) in Southern Lagoon, Belize (Lat/Lon: 17° 12’N, 88° 20’W) and Florida manatees in Crystal River, FL (Lat/Lon: 28° 53’ N, 82° 35’W). These two groups of manatees are subspecies of the West Indian manatee, so comparing the structure of their vocalizations could add to our understanding of the similarities and differences between the two subspecies.

Douglas P. Nowacek

Biology Department, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543 and Sensory Biology and Behavior Program, Mote Marine Laboratory; 1600 Ken Thompson Parkway, Sarasota, Florida 34236

Brandon M. Casper

College of Marine Science, University of South Florida, 140 Seventh Avenue South, St. Petersburg, Florida 33701

Randall S. Wells and Stephanie M. Nowacek

Chicago Zoological Society, c/o Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, Florida 34236

David A. Mann

College of Marine Science, University of South Florida, 140 Seventh Avenue South, St. Petersburg, Florida 33701 and Sensory Biology and Behavior Program, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, Florida 34236

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Recordings of manatee (*Trichechus manatus spp.*) vocalizations were made in Florida and Belize to quantify both intraspecific and geographic variation. Manatee vocalizations were relatively stereotypical in that they were short tonal harmonic complexes with small frequency modulations at the beginning and end. Vocalizations ranged from almost pure tones to broader-band tones that had a raspy quality. The loudest frequency was typically the second or third harmonic, with average received levels of the peak frequency of about 100 dB re 1 μPa. Signal parameters measured from these calls showed the manatees from Belize and Florida have overlapping distributions of sound duration, peak frequency, harmonic spacing, and signal intensity, indicating no obvious distinguishing characteristics between these isolated populations. © 2003 Acoustical Society of America. [DOI: 10.1121/1.1582862]

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II. METHODS

A. Belize recordings

In Belize we recorded sounds on a digital archival tag, the DTAG (Johnson and Tyack, 2003), which simultaneously records the attitude (pitch and roll), heading, and depth of the animal with sounds produced or received by the animal. The hydrophone signal was digitized continuously at 32 kHz. Selected manatees were encircled by a seine net in shallow water and brought aboard the capture vessel for health assessment, measurements, and tagging. DTAGs were attached to three individual manatees via temporary attachments using standard manatee peduncle belts. Floats tethered to the belts carried VHF transmitters for direct radio-tracking, and in some cases a GPS receiver. Sonic tags incorporated into the belts permitted underwater tracking. The tags were recovered either when the belts released via a corrodible link or animals were recaptured for recovery of the DTAG and removal of other tags and belts. Attachments lasted approximately 24 h with acoustic data recorded for 4 or 8 h depending on the tag settings used.

B. Crystal River, FL recordings

Recordings in Crystal River, FL were made using a hydrophone (HTI 96-min; sensitivity $\sim -164$ dBV/$\mu$Pa, 20 Hz to 32 kHz) connected to a data acquisition system (Tucker-Davis Technologies, RP2.1 24-bit ADC) and laptop computer. Signals were acquired continuously for approximately 2 h at 48 828.125 Hz sample rate from an anchored boat with the hydrophone on the bottom at 1-m depth. Recordings were made approximately 20 m away from a group of about 50 manatees that were in the spring. Individuals would occasionally move out of the spring into the spring run to within 2 m of the boat.

C. Data analysis

Data were analyzed with MATLAB (Mathworks, Inc.). Peak frequency (frequency with the most energy) and the level of the peak frequency were determined by performing a 1024-point FFT on a 1024-point segment of the middle of each call. This minimized smearing of frequencies due to changes in frequencies during the call. Harmonic spacing (which is equivalent to the fundamental frequency) was determined by performing an autocorrelation of the FFT, and measuring the first peak after lag zero. Duration was measured by MATLAB with an automatic detection algorithm, and then verified by hand from the spectrogram. While this may lead to a small uncertainty in measuring the time, it was advantageous for signals with low signal-to-noise ratios.
Manatees in Florida and Belize produced vocalizations that were harmonic complexes with small frequency modulations at the beginning and end (Fig. 1). These ranged from almost pure tones to broader-band tones that have a noisy quality. The loudest frequency was typically the second or third harmonic (Figs. 2 and 3). Signal parameters measured from these calls show the manatees from Belize and Florida have overlapping distributions of sound duration, peak frequency, harmonic spacing, and signal intensity (Table I and Fig. 3). Statistical comparisons between these signals were not possible because it is not known which individuals pro-
duced which sounds. Treating each call as a separate replicate would lead to pseudoreplication. The rate of vocalization in Crystal River, accounting for the number of animals present, was 1.29 vocalizations per minute, and in Belize it ranged from 0.09 to 0.75 per minute for the three animals tagged. When alone, the Belize animals were often silent for periods of >10 min. The rates of vocalization we measured were similar to earlier reports (Bengtson and Fitzgerald, 1985).

### IV. DISCUSSION

There are no obvious differences in the vocalizations produced by manatees from Florida and Belize. For the parameters that were characterized (sound duration, peak frequency, and harmonic spacing) manatees from Florida and Belize had overlapping distributions. It is possible, however, that there are differences that we did not characterize.

The finding that the second or third harmonic of the vocalization is usually most intense could be due either to how the sound is produced, or to propagation effects where the lower frequencies do not propagate as well in shallow water, or a combination of the two (Rogers and Cox, 1988). Given that previous research on captive animals also found the fundamental to be less intense (Evans and Herald, 1970; Schevill and Watkins, 1965), our results are probably best explained by the production system of the animals. Indeed, in all of these recordings we do not know the distance to the sound-producing manatee, only a range to the manatees that were in the area. The data from Belize include both the animal wearing the DTAG as well as animals vocalizing nearby. Still the received levels can be taken to show the range of levels that might be produced by manatees, and they are likely within 6–15 dB of source levels given the range of distances over which the recordings were made (assuming losses of 3 dB per doubling of distance).

The motivation for this study was to determine the range of natural variability in manatee sounds, so that a passive acoustic detection device can be developed to warn boaters of the presence of manatees. These data show that West Indian manatee sounds are relatively stereotypical, even between subspecies, in that they are short tonal harmonic complexes, and lend themselves readily to this application.

### ACKNOWLEDGMENTS

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**TABLE I. Basic statistics of sounds recorded from manatees in Southern Lagoon, Belize and Crystal River, FL.**

<table>
<thead>
<tr>
<th></th>
<th>Belize</th>
<th>Belize</th>
<th>Belize</th>
<th>Crystal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9 March</td>
<td>10 March</td>
<td>11 March</td>
<td>River</td>
</tr>
<tr>
<td></td>
<td>2002</td>
<td>2002</td>
<td>2002</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>26</td>
<td>105</td>
<td>208</td>
<td>218</td>
</tr>
<tr>
<td>Peak frequency (Hz)</td>
<td>3180 (727)</td>
<td>7080 (2207)</td>
<td>5560 (2559)</td>
<td>5223 (1937)</td>
</tr>
<tr>
<td>Peak level</td>
<td>97.1 (4.3)</td>
<td>92.5 (6.6)</td>
<td>100.0 (4.7)</td>
<td>103.6 (6.8)</td>
</tr>
<tr>
<td>(dB re 1 µPa)</td>
<td>3180 (728)</td>
<td>4380 (1618)</td>
<td>3630 (1620)</td>
<td>2867 (1059)</td>
</tr>
<tr>
<td>Fundamental frequency (Hz)</td>
<td>0.032 (0.017)</td>
<td>0.161 (0.10)</td>
<td>0.217 (0.098)</td>
<td>0.228 (0.074)</td>
</tr>
</tbody>
</table>

The mean for each data set is shown with standard deviation in parentheses.