Final Report

Passive Acoustic Detection of Manatee Sounds to Alert Boaters

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Abstract
This report describes the results of the development of a device to passively detect the sounds made by manatees. The major accomplishments of this work were:

1. Created library of manatee sounds and distributed to other contractors and FMRI.
2. Tested and implemented two manatee detector devices.
3. Developed and conducted benchtop test of manatee detectors.
4. Developed and conducted field test of manatee detectors.

The main results of this project were that manatees produce tonal-like vocalizations that can be readily detected by signal processing devices. Other signals, such as chewing and flatulence sounds were too low in level to be readily detected.

Review of Test and Development
Manatee Sound Library

Recordings of manatees from Crystal River were made and CD's were distributed to other contractors (Lampl-Herbert, University of Florida, and Randy Warner). The sound library contains 289 files of sound clips of manatee sounds.

The sounds in the manatee sound library were analyzed and basic parameters of these sounds were measured. It was found that they did not differ significantly from the sounds that had been recorded from manatees in Belize as part of a separate project. An unpublished manuscript containing these results that was submitted to the Journal of the Acoustical Society of America is attached as Appendix I.

Manatee Detector

Two manatee detector designs were tested. The first was a simple energy detector that detected manatee sounds based on frequency content and duration (Figure 1). This design was robust in situations of high signal to noise, but performed poorly in situations where the background noise was high. Based on results of the bench test (see below), another design was developed and tested in the field test. This design will not be discussed further.

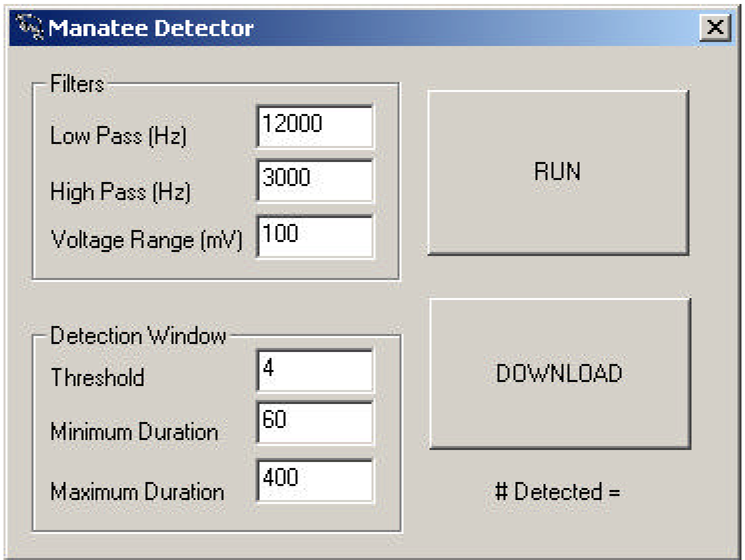


Figure 1. Software interface to configuring manatee detector design #1 (energy detector). The software interface allowed setting of filter pass-bands, and a detection window threshold. It also would download detected signals to a PC.

The second manatee detector design was based on detecting the tonal components of the manatee sounds. This design involved three steps:

1. Filtering the incoming signal to the manatee sound range. While this setting is flexible, it was set to 4000-7000 Hz for the detector tests.
2. Measuring the peak frequency of sounds in real-time.
3. Determining whether the peak frequency stays within a certain range for a certain amount of time.

This design was implemented on a Tucker-Davis Technologies RP2 processor that digitizes and processes signals in real-time. The RP2 was programmed to filter the signal, measure the peak frequency, and determine whether it stayed within a 100 Hz band for a given length of time. The program would send out a trigger signal that was used to light an LED (but could also be used to trigger any external device). The system also stored a time stamp for each detected signal along with a 2000 point signal segment, which could be used to verify the accuracy of detection in a true field deployment.

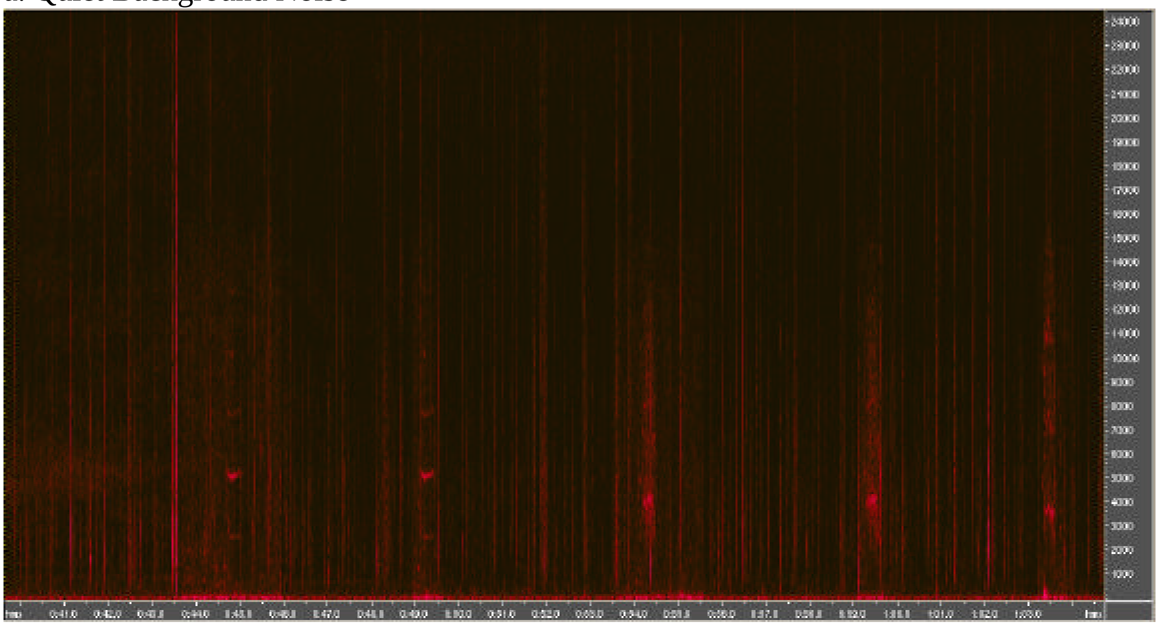
To minimize the effects of snapping shrimp sounds, two parallel circuits were run in real-time with delay offsets.

Bench Test

The bench test was designed and coordinated by Katherine Frisch of FMRI. Forty test sounds were selected for inclusion in this test (selected from both recordings made in Crystal River and recordings digitized by Lampl-Herbert that were originally recorded by Tom O'Shea). These sounds were embedded in the recordings of natural background noise from two different environments (quiet and noisy) (Figure 2). Quiet sounds were recorded off the dock behind Mote Marine Laboratory (near Pansy Bayou). Loud sounds were recorded off the Mote Marine Laboratory dock in New Pass. The idea behind the bench test was that the test signals had a high signal-to-noise ratio. Thus, they could be used to test how detectors might work in different situations by simply adding them to recordings of background noise. Theoretically, this recreates how a manatee would sound in each of these environments.

Copies of these test sounds were delivered as part of an interim report, and were also added to a website (http://www.marine.usf.edu/bio/fishlab/detector_test.htm).

a. Quiet Background Noise



b. Loud background noise

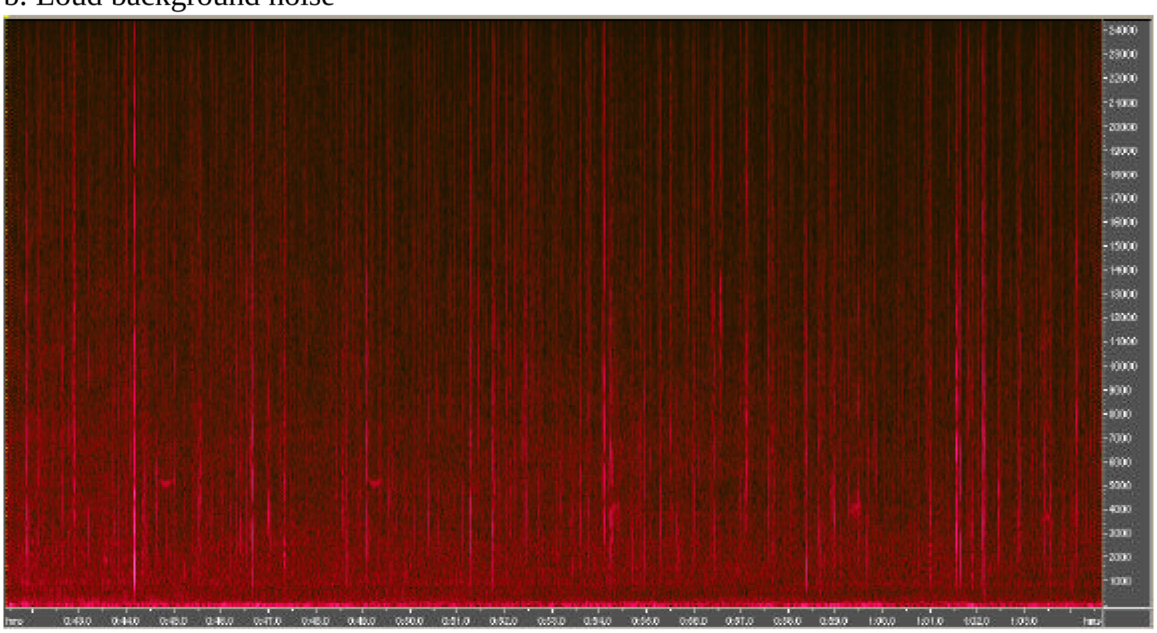


Figure 2. Spectrograms of sample segments of the test sequences used for the bench test. a. Manatee sounds embedded in a quiet background noise. b. Manatee sounds embedded in a loud background noise. Note that harmonics are difficult to pick out in the high background noise sample. x-axis is time, y-axis is frequency (Hz).

Table 1. Summary of results of bench test with detector design #1 and design #2. False alarm rate is calculated as number of false alarms/number of detections.

	'Quiet Background Noise' Detections/ Misses/False Det	'Loud Background Noise' # Detections/# Misses	'Quiet Background Noise' Percent Detected (False Alarm Rate)	'Loud Background Noise' Percent Detected (False Alarm Rate)
detector #1	32/8/0	19/21/37	80% (0%)	47.5% (195%)
detector #2	34/6/0	20/20/0	85% (0%)	50% (0%)

Bench Test Results

The results of the bench test showed that the two detector algorithms has approximately the same rate of detection (around 80-85% for the quiet background noise test signal, and about 50% for the loud background noise test signal). The second detector design eliminated problems with false detections in the loud background noise test signal. These results show the effect of background noise on detection efficiency. The background noise was due largely to snapping shrimp clicks and boat noise.

Field Test

The field test was conducted at the Florida Institute of Oceanography dock in Bayboro Harbor, St. Petersburg, FL. This site has a particularly high background noise from snapping shrimp and boats. Thus, it can be considered a rigorous test site. The field test consisted of playing 100 sounds from our field recordings and from the O'Shea recordings and testing the detection efficiency at two distances (5 m and 10 m). The MATLAB program used for broadcasting signals is attached as Appendix 2. Sounds were played through a hardware system consisting of an RP2 Realtime Processor (Tucker-Davis Technologies, Gainesville, FL), a Hafler amplifier, and two underwater transducers (Aqua Synthesis 225 underwater speaker and an ITC-1042 transducer). Signals during the playback tests were recorded at each of the test sites and placed on the web site (http://www.marine.usf.edu/bio/fishlab/detector_test.htm). Signals were also recorded on DAT tape.

False detections

The rate of false detections was determined by counting the number of detections during a 10-minute period when no manatee sounds were broadcast. No false detections were recorded during the 10-minute test period.

Detection accuracy

The results of the field test are presented in Table 2. The detector performed better at the closer test position, because of the higher signal-to-noise ratio. The majority of the missed calls at both distances were the signals that were less tonal (see Appendix 1 for range of types of sounds produced by manatees).

Table 2. Summary of results of field test with detector design #2.

Distance to Source	# Detections/# Misses	Percent Detected	False Detections
5 m	76/25	76%	0
10 m	37/63	37%	0

Conclusions

This work shows that manatees produce stereotypical calls that are fairly easy to automatically detect. Their tonal nature makes them unlike most other sound sources in the ocean. The two main noise sources that influence detection rates are snapping shrimp clicks, and noise from boat engines. These noise sources limit the ability to detect these signals to fairly short ranges in areas with the highest levels of background noise (on the order of 10 m).

There are several possibilities for increasing the detection range. One is to put out several hydrophones connected to one device to create an array that is capable of detecting manatees over a larger area, and which also could use beamforming techniques to improve the signal to noise ratio. One advantage of this method, is that it could also be used to localize the source, and provide guidance about the best way to avoid manatees.

The greatest technical challenge is avoiding false detections on dolphin sounds, because these are the 'noise' sources most similar to manatee sounds. This work did not explicitly test the rate of false detection on dolphin sounds. That would require collecting information on natural dolphin sounds that was the beyond the scope of this project.

Recommendations for Future Research and Development

The results of this work should be thought of as a "proof-of-concept". It is possible to automatically detect manatee sounds in the environment. There are two types of errors in signal detection, false positives and missed detections. The sensitivity of the detector can be set to adjust the number of false positives and the number of missed detections. There is an inherent trade-off between detecting every manatee sound, and falsely detecting non-manatee sounds. If manatees rarely vocalize in natural situations, the cost of a missed detection can be high. However, if they vocalize at high rates, a missed detection is not very costly.

It is important to emphasize that this proof-of-concept is different than showing that devices based on this technology would be successful in reducing boat strikes on manatees.

There are two main issues that need to be addressed, before test trials of such devices should be initiated. First, how often do manatees vocalize? The recordings made for the manatee library were made in a freshwater spring where at least 50 manatees had congregated. This is a social situation that is largely driven by the cold temperatures of winter. Based on our recording session, it is clear that manatees vocalize enough in these situations to be detected. But, this is not a situation that requires such a device. Manatees are common in these areas in the winter. It is not known how often manatees vocalize in other situations, especially in the summer when they move into bays and coastal areas. In the summer, manatees are spaced much farther apart, and likely vocalize less often.

The second question is how would boaters respond to such devices? It is clear that significant numbers of boaters violate rules in slow speed zones—with between 55-60% compliance (Morris, 1992; Gorzelany, 1996, 1998; Shapiro, 2001). Would boaters use automatic detection devices to avoid manatees, or might some use them to find and approach manatees?

References (see also Appendix I)

Gorzelany, J.F. 1996. Evaluation of boater compliance with speed regulations in Sarasota County, Florida. Final Report submitted to the Florida Dept. of Environmental Protection, 106 pp + app.

Gorzelany, J.F. 1998. Evaluation of boat traffic patterns and boater compliance in Lee County, Florida. Final Report submitted to the Florida Dept. of Environmental Protection, 109 pp + app.

Morris, J.G. 1992. A comprehensive investigation of the compliance with boat speed regulation within the intracoastal waterway and other waterways in Brevard County, Florida. A proposal submitted to the Florida Department of Natural Resources. 19 pp.

Shapiro, S.L. 2001. Assessing boater compliance with manatee speed zones in Florida. Final report submitted to the U.S. Fish and Wildlife Service. Project No. 9322-1602280. 75pp + app

Appendix 2.

```
% pmanatee
% Program to play back manatee m-files
% Copyright 2002, David Mann, University of South Florida

load manatee_b;  % load in filter coefficients

fileprefix='c:\manatee\';

isd=3;  %inter-sound delay in seconds

attenuation=.5;  %6dB attenuation

%Initialize RP2
RP2=actxcontrol('RPco.x',[5 5 26 26])  %Creates an ActiveX Control for
the RP, the second argument controls the placement of the icon in the
MATLAB figure.
invoke(RP2,'ConnectRP2','USB',1)  %Calls the Connect function to the
RP2 (a member of the RP family) using the ActiveX control. Connects to
the first RP2 via the USB port.
invoke(RP2,'LoadCOF','C:\manatee\manatee_play')  %Loads an RP Control
Object (*.rco) file.
invoke(RP2,'Run')  %Starts the RP processing chain.

audio_files=dir(sprintf('%s*.wav',fileprefix));  %get .mat file names
in directory

for us=1:length(audio_files)
    filename=sprintf('%s%s',fileprefix,audio_files(us).name)
    [signal.data,signal.fs]=wavread(filename);

    % normalize to 1 V rms
    normalized=attenuation.*(signal.data/(rms(signal.data)));

    % normalize speaker response
    signal.data=filter(b,[1],normalized);

    % calc dur in ms and write to RP2
    dur=length(signal.data)*1000/signal.fs;
    invoke(RP2, 'SetTagVal', 'dur', dur);

    invoke(RP2, 'WriteTagV', 'signal', 0, signal.data');% load signal
to RP2


   % input('Press Enter to Play Sound')

    invoke(RP2, 'SoftTrg', 1);  %start playing

    playing=1;
    while(playing)
        playing=invoke(RP2, 'GetTagVal', 'playing');
        pause(0.1);
    end
```

```
    pause(isd);
end
save c:\manatee\testsequence audio_files
```