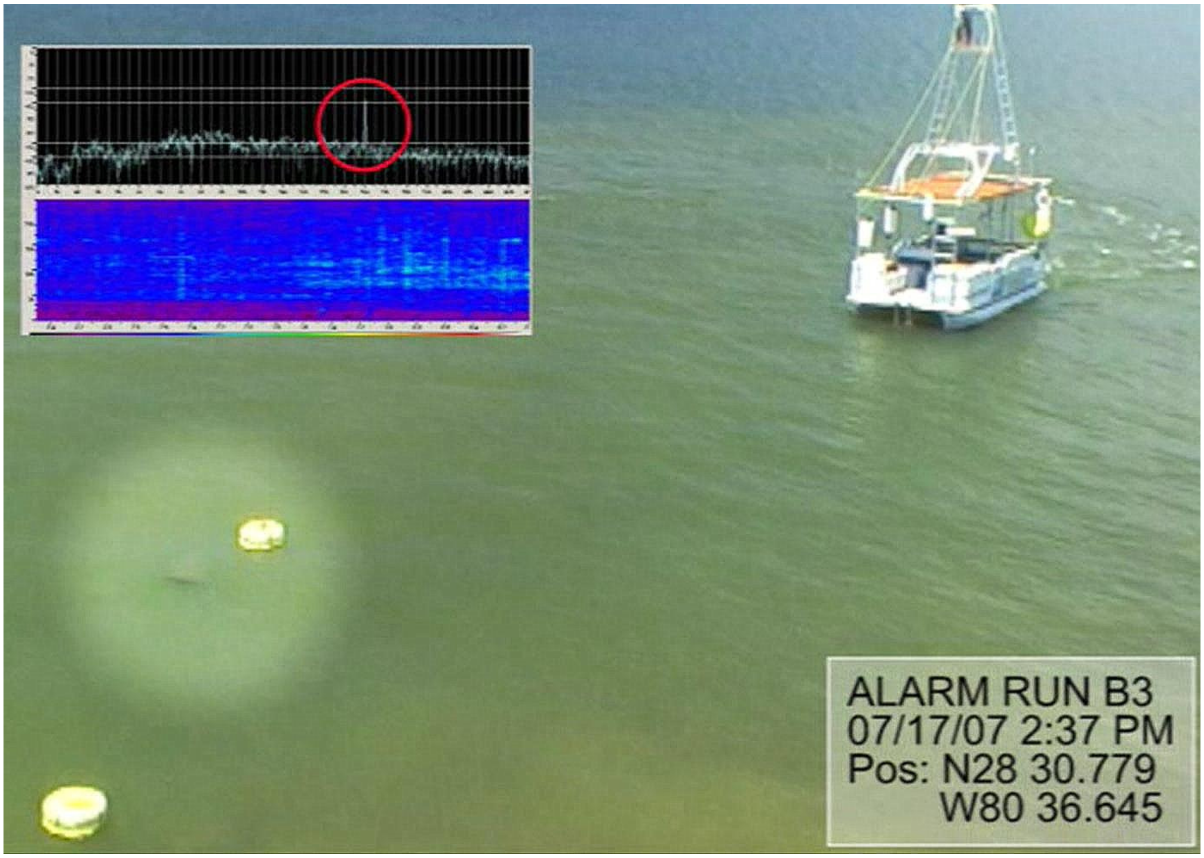
PHASE I: FIELD TESTS OF MANATEE ALERTING DEVICES WITH WILD MANATEES

ANNUAL REPORT



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DEDICATION

This study is dedicated to the memory of Dr. Joseph E. Blue, a visionary physicist, acoustician, and inventor who conceived a method to help save manatees and other marine mammals from collisions with vessels.

SUMMARY ABSTRACT

The purpose of the study is to evaluate the efficacy of an underwater acoustic alarm for alerting manatees of approaching boats and barges. This report summarizes activities for the first field season and details the methods and preliminary results of this research effort. The research was designed to document the behavior of wild manatees prior to, during, and after controlled slow boat approaches. Two experimental conditions were tested; (1) boat approaches without an acoustic alarm, and (2) approaches using the same boat with an alarm. In accordance with the Special Conditions of United States Fish and Wildlife Service (USFWS) Endangered Species Permit MA063561-2, this study was segregated into two phases. This report describes Phase I, in which all controlled boat approaches were conducted with an electric outboard engine. This phase was deemed necessary by the USFWS in order to conduct a cursory evaluation of manatee reactions to alarm sounds in the absence of typical gas engine noise and to insure field techniques were adequate for identifying individual manatees before progressing to Phase II which authorizes a gas powered boat for controlled approaches. The field effort was conducted in the upper Banana River within the USFWS Merritt Island National Wildlife Refuge (MINWR), adjacent to the NASA Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAS), in Brevard County, Florida, and further authorized under MINWR Special Use Permit 2006 SUP 47.

The MINWR site is in a restricted security zone of the KSC where public boating is not permitted. This provided relatively controlled conditions with few anthrogenic and related acoustical variables to influence manatee behavior. Brightly numbered buoys, each configured with a corresponding GPS, calibrated digital acoustic recorder and submerged hydrophone were used to both acoustically and visually grid the study site. The digital recorders were synchronized with each other and areal video recorders to document manatee behavior and the associated received acoustical conditions throughout the site and at the focal animal during control and experimental conditions.

The field effort was conducted April 1 through August 7, 2007. Manatee observations, site bathymetry, acoustic propagation and calibration measurements were conducted throughout the season. Though we were on the water a total of 45 days, unseasonably sustained high winds limited the number of days that were suitable for attempting controlled approach trials. Weather, rough surface conditions, dependent visibility factors and the presence of manatees within our buoy fields yielded 11 usable days for controlled testing. During these 11 days, a total of forty-nine controlled boat approach trials were successfully completed. Forty-three (88%) were *no-alarm* trials and six (12%) were *alarm* trials. Only seven percent (7%), three of the forty-three of the *no-alarm* approach trials elicited an avoidance reaction

or change in behavior before the boat came within three body lengths (≤ 8m), and was forced to veer away from the focal manatee. In contrast, one hundred percent (100%), six of six *alarm* trials elicited overt avoidance responses (swimming away or diving) at 15-25m distances ahead of the bow. The mean distance away from the approaching boat at which focal manatees responded was significantly greater during *alarm* trials ($F = 143.42$, df=1, $p < 0.01$) than the *no-alarm* trials. The mean change in behavior during approach trials was also significantly greater during the *alarm* trials ($F = 76.74$, df=1, $p < 0.01$).

Shallow water propagation constraints along with Lloyd's Mirror Effect resulted in significant transmission losses at frequencies ≤1 kHz which could account for the lack of response during *no-alarm* approaches. Applying conservative critical ratio estimates for broadband noise, manatees could not detect the sounds associated with *no-alarm* boat approaches at distances ≥ 9m. Manatees responded to alarm sounds at received acoustic levels ≥ 18 dB above their estimated critical ratios.

Photo-identification procedures were conducted in consultation with the U.S. Geological Survey Sirenia Project. Digital photography and videography from an extended tower, elevated boat platform and bridge at the MINWR site proved to be reliable and 30 individual manatees were positively identified and catalogued. We conducted controlled approaches with 19 identified manatees. Of these 19 individuals; 3 were approached four times; 4 were approached three times; and 7 individuals were approached two times. No individual was approached more than four times. Six unidentifiable individuals were approached over the 11 days. Five of the six *alarm* runs were conducted with identified manatees that had previously been approached during *no-alarm* runs. These same individuals did not react during *no-alarm* approaches but all exhibited avoidance reactions during the *alarm* approach.

Justification for progressing to Phase II in order to repeat tests with more typical gas boat configurations is provided within this report.

STATEMENT OF PROBLEM

While manatees are repeatedly scarred and often killed by collisions with watercraft, the root causes of collisions, and how to effectively mitigate the frequency of collisions is greatly debated. Gerstein and Blue have argued since 1996 that near surface propagation characteristics and shallow-water transmission loss in concert with the manatees' unique auditory constraints are underlying sensory causes of many, if not most, of the collisions with boats and barges. While encounters with slow moving commercial vessels are often fatal, most encounters between recreational boats and manatees are not. Many individual manatees survive and bear the scars from multiple boat encounters. These encounters are so prevalent that manatees are routinely identified by characteristic scar patterns from boats and propellers. One individual recently killed by a fast moving boat exhibited 50 scar patterns from different boat collisions. Gerstein and Blue argued that the majority of fatal commercial and non-fatal recreational boat collisions result when the dominant lower frequency sounds of boats are attenuated near the surface and their propagation is limited in shallow water habitats. Lower intensity sounds produced by slower propeller rates are also more readily masked by ambient levels typically recorded in the Atlantic Intracoastal Waterway and other brackish and shallow water habitats.

A comprehensive series of controlled underwater psychoacoustic tests was conducted to measure and document the overall hearing abilities of the West Indian manatee. Pure tones, complex noise and real world sounds were presented to manatees under various controlled acoustical conditions. The results from more than 30,000 threshold trials definitively measured the manatees' overall range of hearing, sensitivity, masked thresholds, critical ratios, and directional hearing for pure tones, species specific calls and boat noise. Complementing these investigations, underwater acoustical measurements of manatee habitats and vessel noise propagation in these environments were conducted to evaluate the acoustical factors that render Florida manatees vulnerable to repeated collisions with vessels. Both low frequency cut-offs in shallow water and near surface boundary effects limit the propagation of low frequency sounds and the dominant low frequency spectra of slow moving boats. Slow speed zones implemented to protect manatees do not address the underlying acoustical challenges manatees face. Ironically, the strategy can also be counter-productive in turbid waters and exacerbate the problem, making vessels more difficult or impossible for manatees to detect while increasing transect times and thus the opportunities for collisions. While manatees are not adapted for hearing the dominant low frequency spectra from watercraft they are well equipped to detect and locate higher frequency modulated sounds. This hearing sensitivity provides a narrow sensory window through which to alert manatees of approaching vessels. Understanding the propagation characteristics of their shallow water habitats Dr. Joseph E. Blue, an expert in sonar technologies and transducer design, conceived of a method to exploit the manatees' best hearing abilities and alert them to the presence of motor boats and commercial vessels. In 1998, he was awarded a Methods patent on the application of acoustic alarms to help manatees detect and locate approaching boats. The Florida Inland Navigation District (FIND) and the Florida Fish and Wildlife Conservation Commission (FWC) supported the development of two working prototypes of the Blue-Jette Manatee Alert Device; unfortunately, Dr. Blue did not survive to see a permit issued to test this technology. This work is dedicated to his memory.

After a protracted permit review period, the USFWS added a supplementary phase to the original research design requiring that controlled boat approaches toward manatees be conducted with an electric boat to better isolate the reactions of manatees to the sound of the device and to work out field protocols for identifying manatees at the MINWR site. Phase I does not support the statistical rigor of Phase II but utilizes the same field protocols to document behavior and identify individual manatees prior to, during, and following controlled single slow boat approaches. This report summarizes field activities and details the methods and results for the 2007 Phase I research effort.

CONTRACTS, PERMITS AND EXTENSIONS

In October of 2004, FIND awarded a Cooperative Assistance Grant to Florida Atlantic University (FAU) to conduct this study. The FWC agreed to cost-share the study with FIND but could not contract with FAU until December of 2005 after an amended USFWS endangered species permit MA063561-1 was awarded. The MINWR facilitated the approval of the research effort in the Banana River adjacent to the Kennedy Space Center in Brevard County and granted a Special Use Permit No: 006 SUP 47 on May 6, 2006 to operate motorized boats (including the electric boat) in the MINWR. The FWC purchased the electric boat required for the study but it was not registered in time for the 2006 field season. The DMA awarded a revised permit changing a 2005 start date to 2007 in order to recover the lost seasons. FIND and FWC provided no-cost contract extensions to conduct the work. The current USFWS endangered species permit of record is MA063561-2.

MATERIALS AND METHODS

PREPARATIONS, LOGISTICS AND EQUIPMENT MODIFICATIONS

Prior to initiating contracts, planning and consultations with MINWR and Dynamac Corporation biologists, along with NASA and CCAS security and operation officials, began in 2005. Site-specific safety and security concerns required equipment modifications and alternate technologies to conduct the study in the MINWR and NASA restricted area. We had originally planned to use Sparton AN/SSQ-57SPC sonabouys to provide wireless real-time underwater acoustical recording through tuned FM receivers and a multichannel PC digital recording system. The sonabouys and their respective frequencies assignments were provided as part of a technology sharing agreement with the United States Naval Undersea Warfare Center, Underwater Sound Reference Division for use in this study. While NASA security and operational officials reviewed the research and approved the broadcast frequencies and field protocols for the study, the frequency coordinator for the USFWS raised objections and insisted we obtain an FCC license to use the Navy sonabouy frequencies. The FCC could not license military bands so we elected to modify and replace FM broadcasting sonabouys with synchronized autonomous digital flash card recorders. Since these recorders did not broadcast, FCC licensing was not required. The recording buoys proved to be a good alternative as they provided better acoustic fidelity than the original wireless system. However, these buoys recorded acoustic data continually after deployment which made data reduction more labor intensive than originally planned.

During April and May of 2007, exceptionally high winds presented a logistical challenge for launching and securing a tethered blimp from our research boat. For safety reasons we eliminated a blimp video platform and compensated by adding a 6.5m high observation deck and an extended 14m video tower to the approach boat. We also positioned a video camera on the 18m NASA Parkway bridge to provide a fixed unobstructed vantage point for documenting manatee behavior and controlled boat approaches.

To minimize costs and maximize on-site efforts, we rented a large house in Cape Canaveral, Florida three miles from the CCAS gate. The house served as lodging, as well as a field laboratory. Here equipment was maintained, assembled, calibrated and tested. Accumulated acoustical, GPS, photo-ID and video data were downloaded each day onto four 500 GB hard drives for cataloguing and analysis. The research team lived and worked together.

SITE SELECTION

In consultation with the MINWR and Dynamac biologists, we selected an area in the upper Banana River, north of the NASA causeway where public boating was not permitted and manatees were routinely observed in clear water (Figure 1a).

Figure 1a. Overview of site north of NASA Parkway causeway. The two primary areas were White Point and the causeway bridge. Observations and a few approaches were conducted at the Flats and Cove areas.

The area provided relatively controlled conditions with few anthropogenic and related acoustic variables to influence manatee behavior and had previously been the site of a manatee soft release program. The site had expanses of shallow flats that were 1–5m deep that were laden with grasses. It supported a large biomass of sea grass and during the 2007 season approximately 800 manatees were observed in the NASA vicinity by Dynamac survey crews. We routinely deployed buoys in the shallow water (2-5m) adjacent to deeper water drops that were 10-13m. There were two deeper channels (10-12m deep) and two holes (10-15m deep) adjacent to the areas where we set buoys. The substrates were mud mixed with sandy patches in the shallows and silt and mud in the deeper channels and holes. The majority of controlled approaches were conducted in two areas, White Point and the causeway bridge. White Point had a shallow shoreline surrounded by a deep hole. The site had vegetation and patches of sand which provided good contrast for viewing and identifying individual manatees (Figure 1b).

Figure 1b. View of White Point from the lower viewing platform on the approach boat.

Figure 1c. Helicopter view of a buoy set at White Point area. Note the lone manatee to the left (alas not in the buoy field). *(Photo courtesy of Eric Reyier, Dynamac).*

The boat launch at the bridge site was a natural shallow soft shell bank which eroded under windy conditions. Each day it was necessary to level the site in order to safely launch the heavy battery laden electric boat.

AUTONOMOUS ACOUSTIC BUOYS

To both visually and acoustically grid each test site, bright yellow floatation buoys were numbered and instrumented with WAAS enabled GPS units and Digital Acoustic Recording Packs (DARP). Magellan Meridian Marine GPS units mated with SRVY-XM data loggers or Garmin eTrex were enclosed in clear waterproof cases and attached to the top of each buoy. DARPs were configured with an M-Audio Microtrack 24/96 two channel recorder, a Sonic Studios BC-MT 24 hour external battery sled, along with a microphone and walkie talkie. DARP components were assembled and enclosed in correspondingly numbered watertight Pelican cases which were attached to the buoys alongside the smaller GPS cases. A sealed external cable ran from each DARP to a calibrated U.S. Navy USRD F37 hydrophone standard that was suspended 1.5m from the surface (Figure 2a, 2b).

Figure 2a. DARP components: two channel digital flash card recorder, power sled, walkie talkie, microphone, and hydrophone.

USRD F37 hydrophones were selected for their robustness and flat frequency range of 10 Hz to 37 kHz at 0 to 35°C. They were omnidirectional in the horizontal plane and narrow in the vertical plane which worked well for detecting boat and biological noise and minimized noise contamination from surface interactions with the buoys.

Figure 2b. Numbered buoys helped to grid areas visually as well as acoustically with both GPS and DARPs.

The Mircrotracks were configured with 8 GB flash cards. Both channels were sampled at 48 kHz and written to 16 bit *.wav* file formats. The Nyquist frequency was adequate for recoding ambient noise, as well as the boat and alarm spectra, while providing up to 11 hours of continual recording. The left channel recorded underwater noise via the hydrophone and the right channel recorded walkie call tones and voiced narration which annotated events and time. The call tones and narrations served to synchronize the acoustical and video recordings.

Eight instrumented buoys were deployed at varying intra-buoy distances ranging from 5 to 20m to grid areas ranging from 100 to 500 square meters. Buoy tethers of varying lengths were covered with garden hose to negate any possible entanglement risks for manatees (Figure 2c). They were quietly deployed using a kayak to minimize disturbance to manatees in the area (Figure 2d). Deployments were completed at least one hour before any controlled boat approaches. Once deployed, the network of buoys formed a static acoustical receiving field in which manatees foraged, socialized, traversed and/or rested. Buoys were retrieved each day and DARP and GPS units were powered down. The numbered flash cards from each recorder were downloaded and catalogued along with their GPS coordinates. The DARP components were recharged and batteries were changed as needed.

Figure 2c. The buoy anchoring system negated risks of possible entanglements with any curious manatees.

Figure 2d. Buoys were soft deployed using a kayak to minimize any possible disturbance to manatees in the area. These deployments were made at least one hour before any controlled boat approaches.

ELECTRIC APPROACH BOAT

In accordance with the conditions of our permit, an electric powered boat was used for controlled approaches. During the course of this project the boat was powered with two different electric engines, a Reservoir Runner 500 (RR) and a Ray Electric Outboard 500. The FWC generously provided a customized 6m long, 2.5m beam aluminum pontoon boat configured with the RR outboard. A pontoon boat was selected for the electric conversation because it provided the most deck space and efficient hull design for electric propulsion. The RR engine was manufactured by Graham Consulting and Engineering Inc., http://www.qis.net/~jmgraham/rr500spc.htm. This outboard was a modified 2004 Johnson outboard in which the power head was replaced with a permanent magnet 72 volt electric motor. The RR propeller was shrouded in a Knort nozzle which provided good efficiency and protected manatees (Figure 3a). Early in the course of the study the RR engine failed on two separate occasions and needed to be shipped back to the manufacturer each time for repairs. We replaced it with a Ray engine, http://www.rayeo.com/motors.htm. This engine was also a permanent magnet engine. A propeller guard was fabricated to protect manatees and this engine was used to conduct the controlled approaches (Figure 3b).

Figure 3a. RR engine

Figure 3b. Ray 500 engine

A compliment of twelve 6 volt marine batteries was necessary to power the boat and they were distributed port and starboard under the seats and also at the stern. In addition to 1000 lbs of 6 volt batteries, four 50 lbs / 12 volt deep cycle batteries and two pure sine wave inverters were on board to provide clean AC power for computer monitors, video and electro acoustical equipment. The boat's electromagnetic field posed interference challenges but this was resolved with shielding around the cables and batteries. Loaded with equipment and with four researchers onboard, the maximum obtainable speed with either engine was 5 mph (Figure 3c).

Figure 3c. Boat docked at the causeway bridge area before loading.

This boat served as both the approach boat and platform from which we observed manatees during controlled periods as well. High winds and associated safety concerns negated the use of the tethered blimp camera platform while at the NASA / MINWR site. As previously noted the boat had an elevated observation deck, a 6.5m high tuna tower and an extended 14m video pole for wide angle viewing. These platforms provided adequate vantage points for photo-identification, real time tracking and videotaping manatees (Figure 4a).

Figure 4a. Boat shown with RR engine, elevated viewing decks and 14m extended remote video camera.

The approach boat was also equipped with a Garmin GPSmap 545s sonar and map plotter to record boat tracks, position, time, speed, water depth and water temperature throughout the day. The boat GPS and buoy GPS coordinates were downloaded to a dedicated hard drive and plotted in the lab using Garmin Map Source tools and Google Earth Plus. Figure 4b illustrates some sample boat tracks and buoy sets at the NASA parkway causeway bridge and White Point areas over time (Figure 4b).

Figure 4b. Sample boat tracks and buoy sets at the NASA parkway causeway bridge and White Point.

BATHYMETRY AND NOISE PROPAGATION

Ambient noise surveys, along with site-specific bathymetry and propagation measurements were taken throughout the season. Ambient noise was measured continually with all DARPs at a sampling rate of 48 kHz. The recorders were synchronized periodically throughout the day using walkie call tones. Recordings were further annotated by narrating times and conditions using the walkie channel on the recorder. Site specific bathymetry and sound speed profiles were recorded at each area using a Falmouth Scientific, Conductivity, Temperature, and Depth probe (CTD). CTD casts were conducted off the sides of the boat at various depths throughout the study site, and in the same locations as controlled boat approaches, and the data was recorded directly to a laptop onboard the boat (Figure 5a).

Figure 5a. Site-specific bathymetry, and sound speed profiles were measured using CTD casts from the boat.

Active noise propagation (transmission loss) tests were conducted from the boat using a calibrated sound source and projector. A Navy USRD J9 projector was soft mounted at the bow of the boat and submerged to a depth of 1m. The aperture of the projector was orientated toward a line of instrumented buoys positioned at varying distances from the projector. A reference buoy was set 2m from the projector, and the other buoys ranged in distance out to 100m. Two types of signals, linear sweeps from 0.1- 20 kHz and 1/3 octave noise bands, were generated with a Stanford Research Systems (SRS) DS 360 function generator and a Carver CB15 amplifier. The signals were monitored with a SRS 770 FFT Network Analyzer. Acoustical transmission losses were measured over center frequencies at 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, 10 kHz, 15 kHz and 20 kHz. A laser range finder was used to estimate surface distances and help line up buoys. In the field lab, GPS time and location coordinates at each buoy were used to accurately determine the transmission losses across buoy distances (Figure 5b).

Figure 5b. Propagation (transmission loss) measurements were made using a calibrated USRD J9 projector directed along a line of instrumented buoys anchored at varying distances.

SOUND SPEED PROFILES

CTD measurements revealed a negligible speed velocity gradient (0.1m/s) in the very shallow areas where the high winds evenly mixed salinity and temperature gradients (Figures 6a, 6b). The most significant parameter usually affecting ray bending is the temperature gradient. As expected, sound speed decreased more with depth reflecting a slight negative temperature gradient in deeper channels and holes. At the hole near White Point the sound speed shows a linear decrease 1m/s from 2 to 7m. It then levels at 1,533 m/s and remained steady to the maximum depth of 8m (Figure 6c). The travel time for sound to reach 100 meters at 1,533 m/sec was 0.65s. The diffraction was negligible with respect to manatee reception and propagation loss near the surface. At the bridge, the sound speed decreased linearly 0.5m/s over a depth of 7m, and then leveled at 1,533.5 m/s to a maximum depth of 7m (Figure 6d). Downward ray bending was considered negligible with no significant effect on acoustic propagation over 100m distances.

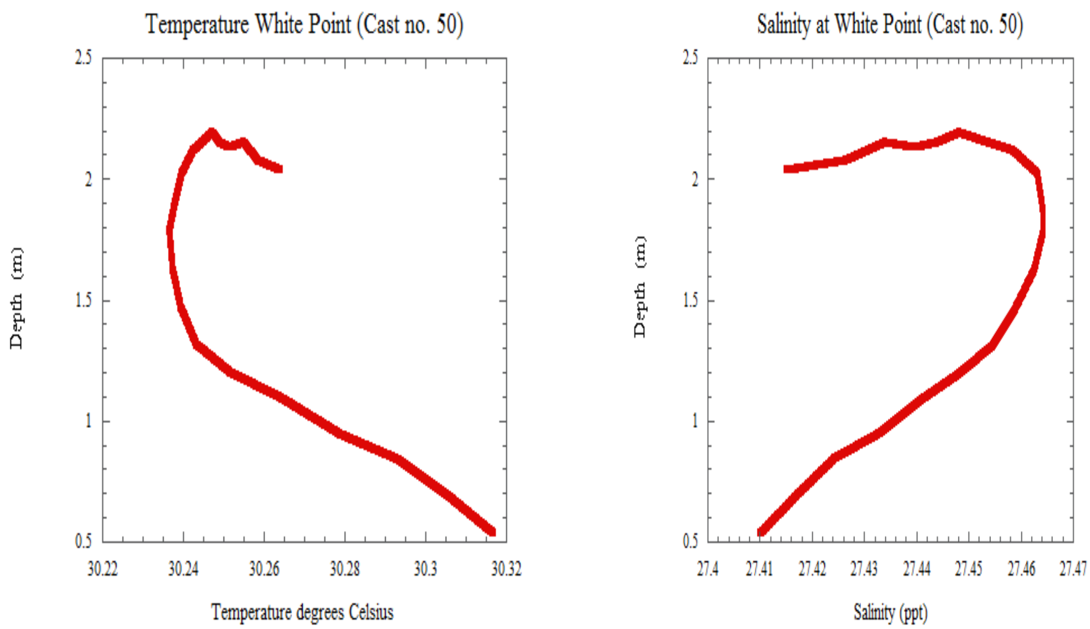

Figure 6a. CTD cast at White Point 6/06/07, windy conditions mixed the thermal and salinity gradient.

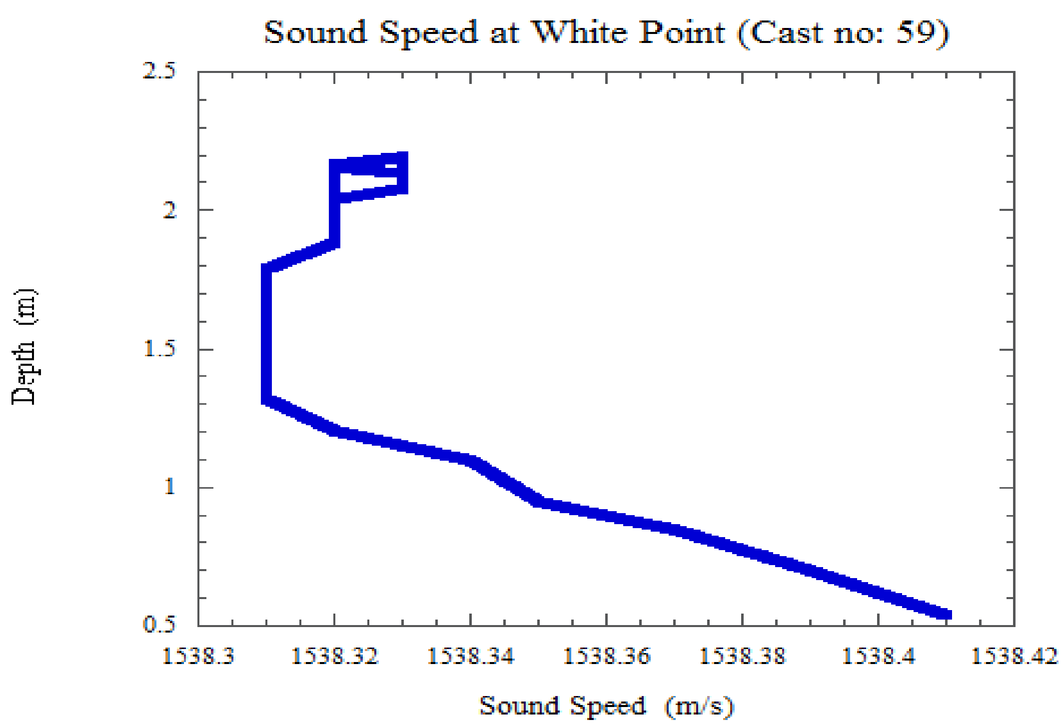

Figure 6b. CTD cast at White Point 6/06/07. Iso-sound velocities in areas where slow boat approaches were conducted.

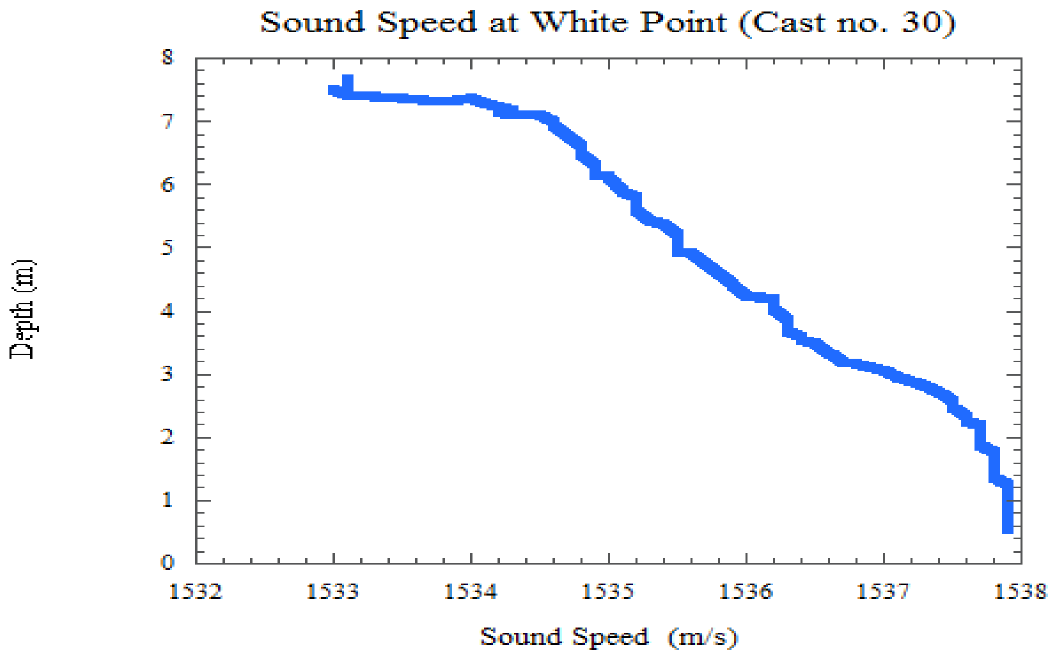

Figure 6c. CTD cast at White Point hole 05/28/07, day of tests near the hole.

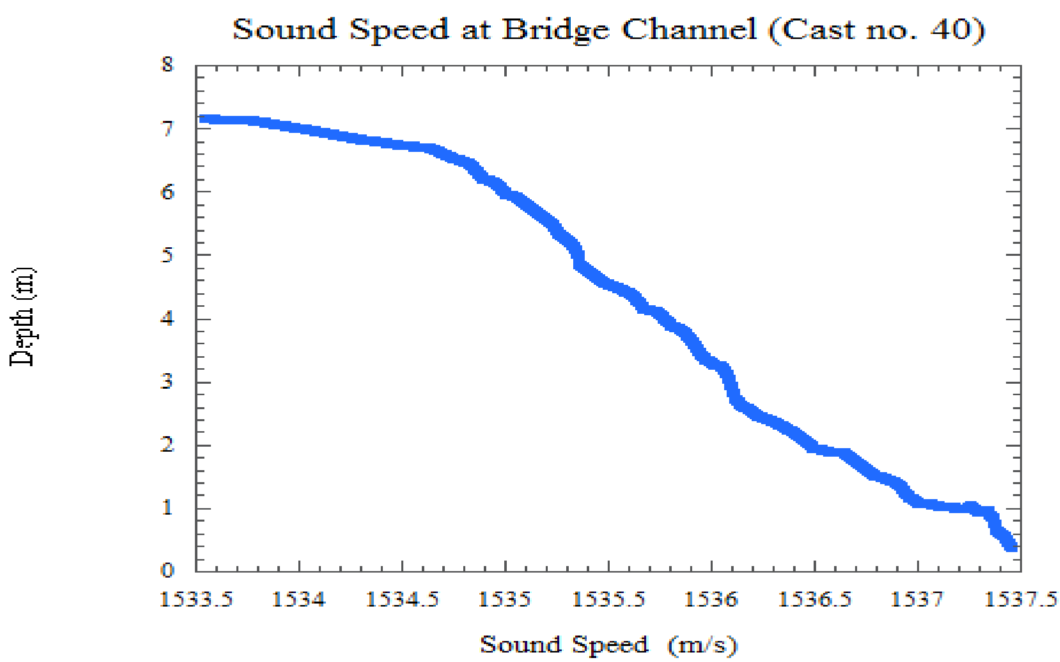

Figure 6d. CTD cast at NASA parkway bridge 05/16/07.

SITE-SPECIFIC ACTIVE PROPAGATION MEASUREMENTS

Site-specific active propagation measurements confirmed that higher frequencies propagated well in the channel and deeper holes, while boundary effects were apparent at lower frequencies in the shallower flats and shoreline areas. Mid-range frequencies (2 kHz to 10 kHz) propagated with the best efficiency while lower frequencies were attenuated by boundary limits of shallow water and the Lloyd's Mirror Effect near the surface. Higher frequencies, however, were more readily scattered by the grasses. Propagation efficiency was dependent in part on the frequency spectra, water depth, surface conditions, bottom substrate and the presence of sea grasses. Site specific propagation measurements confirmed that frequencies ≥ 2 kHz propagated efficiently in the channels and shallow adjacent shorelines (Figures 7a, 7b, 7c) and scattered and attenuated with distance. The results coincided with propagation measurements in the Florida Inland Intracoastal Waterway and in Kings Bay, GA (Gerstein and Blue 1997, 1996). While a magnificent pristine habitat, the propagation characteristics of the NASA site can be found in other shallow grass bed areas and shallow dredged areas (Gerstein et al., 2004). Shallow water and near surface propagation constraints on the dominant spectra generated by boats has been postulated as an underlying cause of watercraft related injuries (Blue and Gerstein 2005; Gerstein 2002; Gerstein et al. 2005, 1996, Gerstein et al. 1999). Transmission loss associated with Lloyd's Mirror and low frequency cut-off limits in shallow water have serious implications for manatees. Their ability to hear low-frequency sounds from slow moving boats, especially frequencies generated by the blade rate of a propeller, is difficult when the animals are near the surface (Gerstein 1995, et al., 1999).

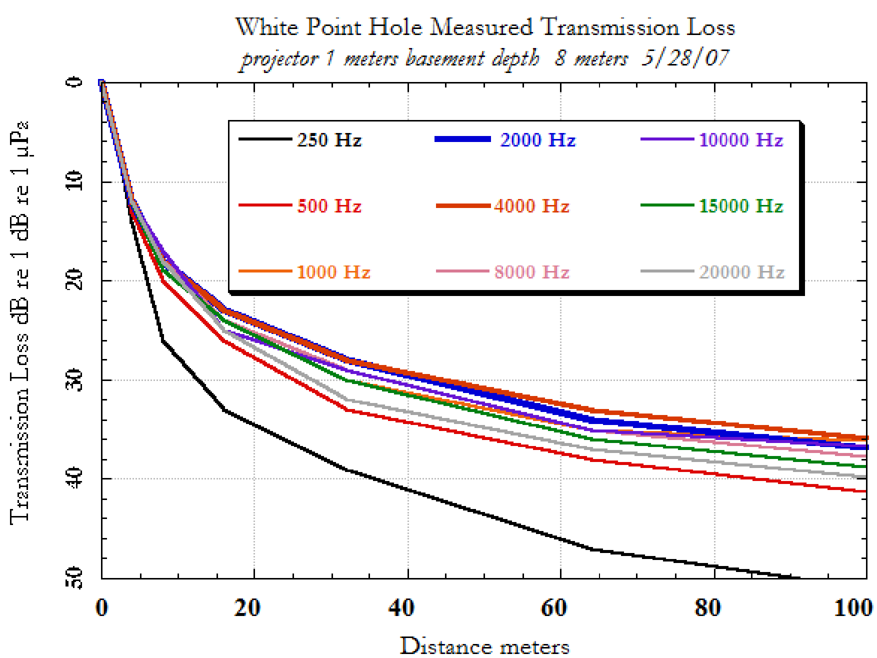

Figure 7a. Transmission loss at White Point.

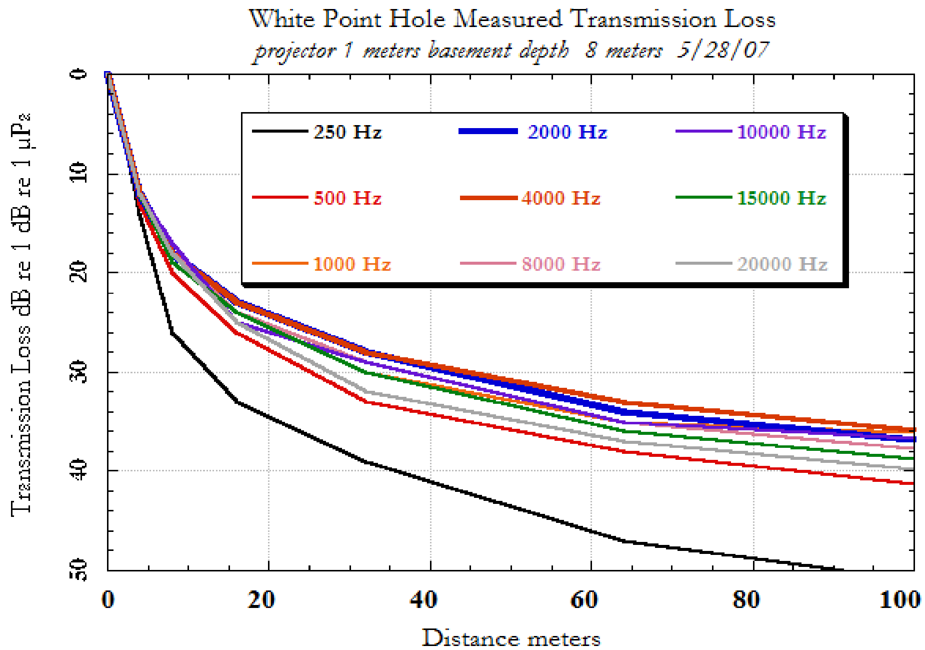

Figure 7b. Transmission loss at White Point hole.

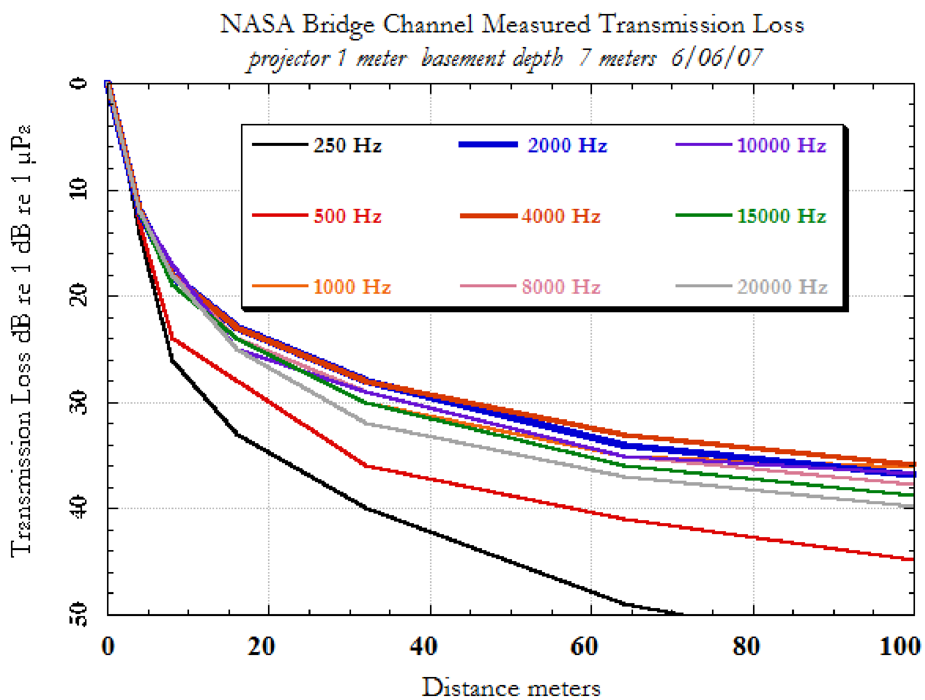

Figure 7c. Transmission loss at bridge area in channel.

PHOTO-IDENTIFICATION AND VIDEO

Nikon D70 and D80 cameras with 70-210 and 70-300 mm lenses and active polarizing filters were used to photograph manatees. Elevated platforms on the boat and the NASA causeway bridge provided good vantage points for obtaining quality images and the opportunity to shoot multiple angles of individuals. Photo-identification procedures were conducted in consultation with Cathy Beck, at the U.S. Geological Survey, Sirenia Project to assure consistency with the Manatee Individual Photo-identification System. More than 900 photos of manatees were taken and reviewed. Thirty four manatees were positively identified and catalogued with a supporting gallery of raw and jpeg digital images. Many more were photographed but did not have distinctive enough features to be readily identifiable. A field photo-identification card for each of these manatees was created to serve as a sighting aid on the boat. A sample of these cards is shown in Figure 8. A significant factor which resulted in good identification matching during trials was our bias for only attempting tests on "perfect" days and conditions when winds speeds were ≤ 5 mph and buoy fields could be set where the water surface laid down. We selected days and areas when the water's surface was often like glass. Most areas were shallow and had patches of sand which offered optimum contrast for viewing manatees. There was little rainfall and the water visibility measured with a Secchi disk often exceeded 6m. Aside from wind, the most challenging element was morning haze and reflection. Though we were on the water early to set up buoy fields we usually did not begin concerted observations or attempt approaches with manatees until after 10:30 AM when reflectivity off the surface was reduced by the angle of sun. Polarizing filters were effective most of the time except during the early morning hours. Limiting our efforts to optimal times and conditions and carefully selecting sites resulted in our ability to reliably identify and track manatees in an area. Our activities did not displace manatees from resting and/or feeding areas, which further added to our success in tracking individuals throughout a day at a particular location.

We used three video cameras with polarizing filters. The first was a Panasonic AG-HVX200 P2 Pro HD video camera. The second was a Panasonic PV-GS320 3CCD camera. Though the P2 camera was capable of 1920 x 1080 HD resolution we chose to shoot 720 lines at 60ps and used a mini DV format to conserve hard disk storage and to simplify viewing and editing. Mini DV tapes were downloaded along with their generated time-codes and catalogued. Two cameras were simultaneously used to provide close up and wide angle views of manatees during experimental conditions. The third video camera was a Panasonic WV-CS-954 Super Dynamic dome camera with a 30x optic lens. This camera was positioned on an extended mast above the boat. It was operated remotely with a Panasonic WV-CU161C pan/tilt/zoom/focus/iris controller. The video resolution was 570 lines and the video signal was stored directly to a laptop hard drive on the boat. Video recordings were synchronized with running time code and with the DARPs, via walkie talkie call tones, at the onset of each video sequence and before the end of each recording. One hundred and sixty seven hours of video were recorded along with 2,432 hours of 2 channel audio. Video segments of the boat approach trials and randomized control periods were compiled for review and scoring at the laboratory. Adobe Premier CS3 Professional was used to match the acoustic and time coded video recordings using the right channel (walkie input) as the synchronization channel.

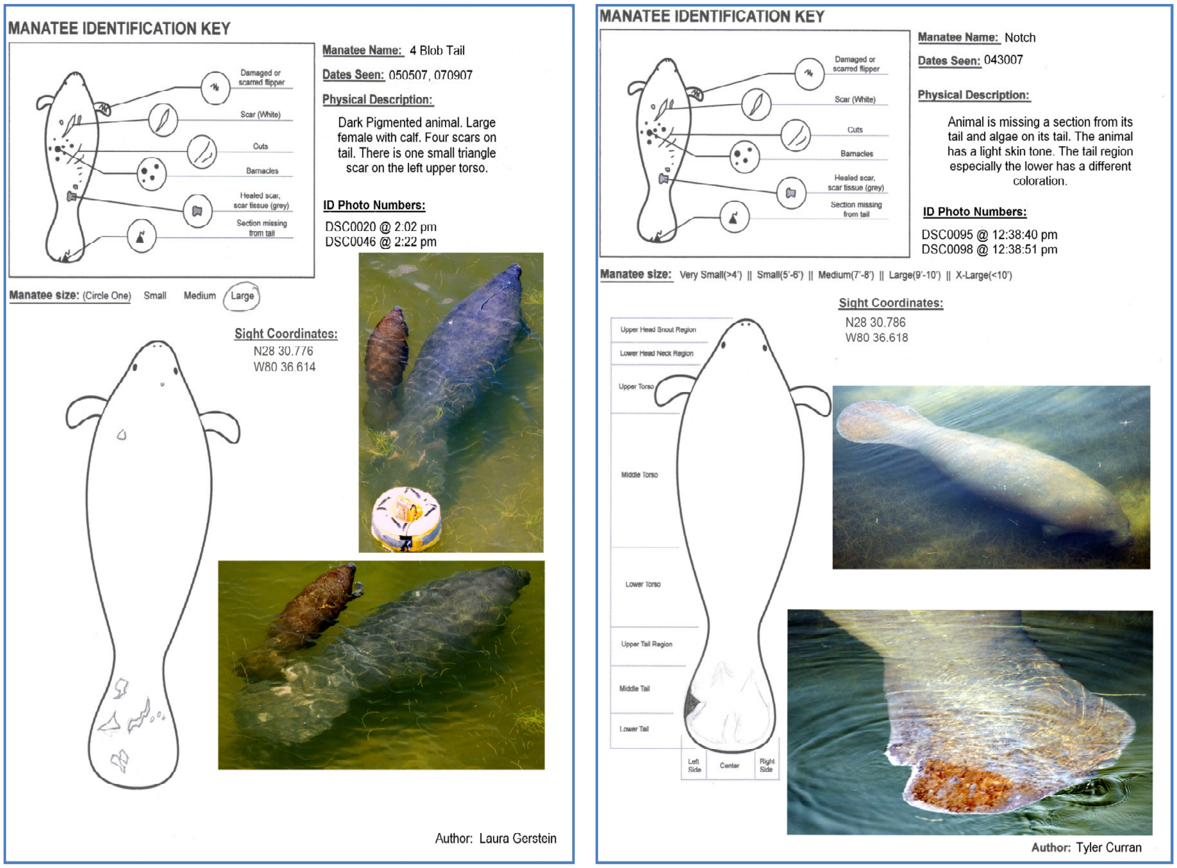

Figure 8. Sample of field identification cards for catalogued individuals.

THE ALARM

The Florida Wildlife Conservation Commission, Florida Inland Navigation District and U.S. Department of Defense Navy supported the development of two prototype Manatee Alert Devices. A report on the prototypes and specifications is provided on the FWC website, http://research.myfwc.com/engine/download_redirection_process.asp?file=gerstein_report_4353.pdf&objid=14362&dltype=article . We used one prototype at a time and kept the other as backup in case of failure. The prototypes utilized nonlinear (parametric) acoustic methods to generate very narrow beam alarm sounds in front of the approaching boat. A detailed technical report on the theory, design and hardware specifications of these prototype devices was submitted to the FWC and FIND (Gerstein 2002). In summary, the alarm system utilized parametric techniques to generate narrow 6° acoustical beams of sound directly ahead of the boat. Two identical finished prototypes are shown in Figure 9a. They had single side band generators (SSB) combiners, power amplifiers and parametric acoustic projectors. These prototypes were robust and designed with flexibility so they could be modified and fine tuned in the field during tests with wild manatees.

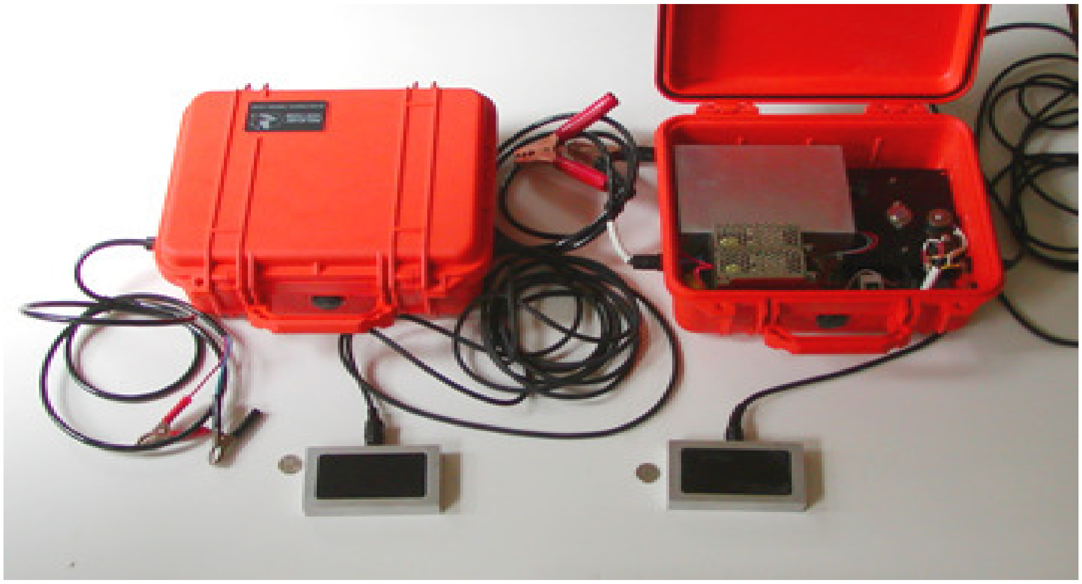

Figure 9a. SSB, combiner, power amplifier and acoustic projector.

Modulated 10-20 kHz signals, which captive manatees reliably detected and located against high ambient conditions, were derived from previous psychoacoustic investigations (Gerstein et al. 1997). These modulated signals were imputed into the SSB and combiner electronics to produce the alarm sounds. With a maximum power of 1 watt the resulting SPL was 120 dB re 1µPa at 1m. The projectors were comprised of 45 element planar arrays with 5 rows of piezoelectric piston elements, 9 elements per row (Figure 9b).

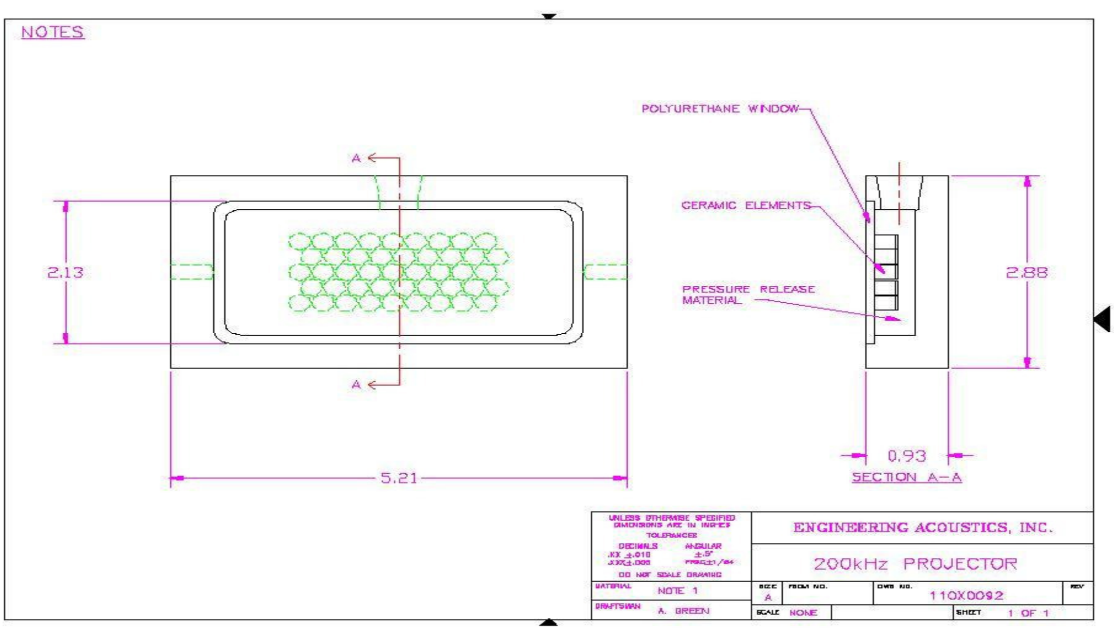

Figure 9b. Thickness mode resonance projector layout.

Navy Type I ceramic was chosen for its good piezoelectric and thermal properties. Its high Curie point (~ 325° C) insured the projectors can withstand high temperatures that could build up should it be operated in a continuous wave mode. The projectors were encased in Aluminum 6030 and structurally reinforced for universal mounting. They were mounted in an armature bolted to the center of the bow. The armature telescoped down and submerged the projector 1 meter below the surface at the bow in a forward facing position.

ACOUSTIC DATA PROCESSING AND ANALYSIS

Buoys were retrieved and the numbered flash drives from each two-channel recorder were downloaded each day. Approximately 64 GB of acoustic data was downloaded following each deployment. The associated GPS time and position coordinates for each buoy were linked and catalogued with the acoustical data on dedicated hard drives at the field laboratory. The acoustic data sampled at 48 kHz was written to 16 bit *.wav* files. Since the recorders were started at different times and then continuously recorded throughout the day, time series recordings in the windows *.wav* file format had to be aligned with each other. Synchronization was straightforward as the right "walkie" channel was dedicated for this use. Adobe Premier Professional and Cool Edit were both used for aligning *.wav* files from the recorders. Adobe Premier Professional was used to synchronize the time coded video recordings with these *.wav* files. The SRS 770 Network Analyzer was used at the field laboratory to perform calibrated frequency and amplitude analysis. The basis for data analysis for ambient noise and vessel noise was the Fourier Integral Transform for continuous spectra. Time series, averaged for relatively stationary sources and ambient noise, were sampled over long periods up to 5 minutes. When considering boat noise and the respective distances from each hydrophone buoy, noise was integrated over finite time intervals. The effect of doing this was to fix the noise in a statistical sense over a specific time interval. Multiple sampling periods to capture approaching boat noise at specific distances (moments in time) ranged from 200-500m/s. For this report FFT plots are present as 400 point spectra from 0.01- 22 kHz with a minimum resolution of 64 Hz. A Blackman-Harris window was employed to minimize leakage because it provides a narrower main lobe with smaller side lobes, and better amplitude accuracy (0.7dB versus 1.5dB) with a Henning window.

Acoustic data is presented as FFT plots with spectral magnitudes (amplitude and sound pressure level) referenced in dB re 1 μPa at the noted received distances from the recording buoy. Peak hold (Pk) and averaged Root Mean-Squared (RMS) curves are presented. Pk plots capture the highest magnitude for each frequency in a sampled time series or *.wav* file. Linear RMS averaging computes the weighted mean of the sum of the squared magnitudes. This reduces fluctuations (spikes) in the data but doesn't reduce the noise floor. The RMS plot being an average over time, instead of a selective representation of the highest amplitudes over time, is lower than the Pk curve for the same sample. The difference between RMS and Pk values is dependent, in part, on the size or duration of the sample and the frequency spectra within the time series.

AMBIENT NOISE

Ambient noise was recorded continually with the buoys at a sampling rate of 48 kHz. This sampling rate provided a broad enough spectrum to evaluate boat noise and alarm sounds while providing the storage capacity necessary for continuous recording. With larger flash memory available, we will be sampling at 98 kHz in 2008. Infinite averaged RMS plots of ambient noise taken throughout the site show the range and diversity of ambient noise in the Upper Banana River where controlled boat approaches were run. The averages were taken during natural ambient conditions when no NASA or Dynamac boats were operating in the vicinity. The dominant low frequency noise is attributed to surface wind and continuous biological noise. Snapping shrimp sounds are ubiquitous throughout the site and ranged from 1-25 kHz, averaging more than 80 dB (Figure 10). Other biological sounds, like the stridulatory sounds of soniferous fish (croakers and drums), were also recorded.

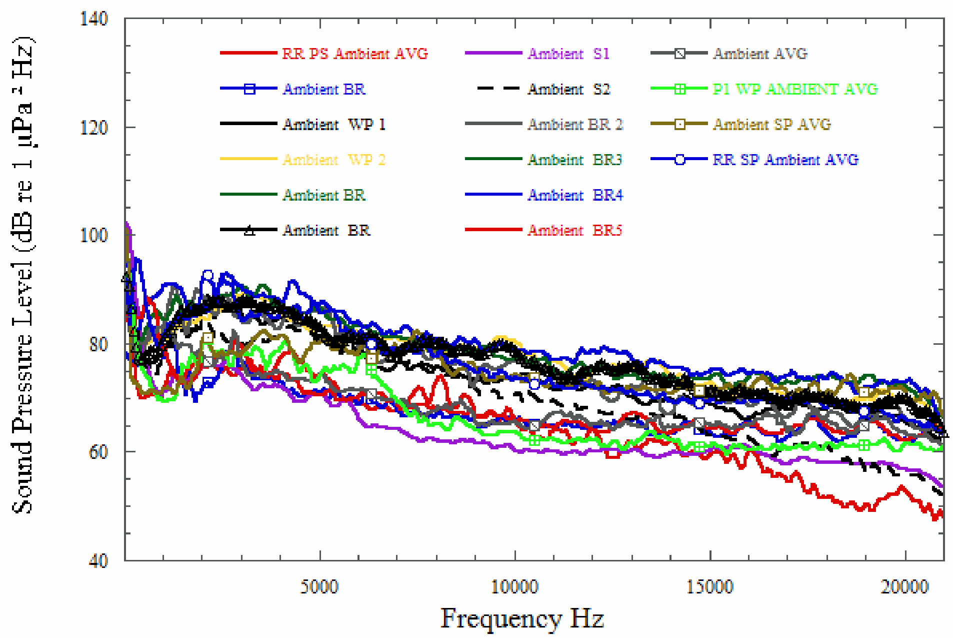

Figure 10. Sample of ambient noise from continuously ruining acoustic buoys. Ambient noise levels are consistent with many manatee habitats where snapping shrimp are the dominant biological contributor.

Sensory adaptations, particularly auditory abilities, are shaped by the acoustical characteristics of the environment. How well manatees can hear "biologically significant" sounds and the sounds of approaching boats is inextricably bound to their perceptual hearing abilities and to the intensity and spectral characteristics and subsequent propagation of these acoustical signals in the environment. This sensory disadvantage is related, in part, to propagation effects and auditory masking. The underlying acoustical causes of collisions did not receive the attention of conservation biologists and regulators until recently. While the cumulative effects of increased traffic and noise on the behavior and physiology of marine mammals are difficult to quantify, the direct masking effect of sound intensity on hearing is measurable and has been documented for many vertebrate species (Fay, 1988). Auditory masking is one of the more thoroughly studied psychoacoustical phenomena across taxa. This is a perceptual phenomenon that occurs when the audibility of one sound is decreased by the presence or occurrence of another sound. For example, having a conversation in a quiet room where the ambient noise level is low is quite different from trying to have the same conversation outside next to a busy freeway. The loud broadband background noise from the freeway obscures or masks the voice of the speaker necessitating the speaker to shout above the noise so the listener can hear. The resulting increased energy under the masked condition can be characterized for our discussion as a Critical Ratio (CR). The moment a signal is detected against the noise, the power of the signal equals the power of the noise spectrum (Fletcher & Munson, 1937). The CR can be derived by subtracting the masking noise (dB) from the masked threshold (dB). For example, when a 1.6 kHz signal is presented against a 90 dB background masking noise, a West Indian manatee requires a signal intensity of a least 114 dB re 1 µPa (the masked threshold) to be able to detect the signal (Gerstein et al., 1997). The resulting CR at 1.6 kHz is 24 dB. This CR is conserved, so that at a higher ambient noise level of 100 dB, the same signal would need to be 124 dB re 1 µPa before the manatee could hear it. This relationship is important as higher ambient noise conditions can conceivably push masked hearing thresholds above the received or even the actual source levels of approaching vessels. CRs for pure tones and masked thresholds for complex and broadband noise have been defined for the West Indian manatee (Gerstein & Gerstein 1997). The lowest masked threshold for broadband noise (actual boat noise and 1/3 and 1 octave band white noise) was 10 dB above ambient (Gerstein 1996, 1997). These masked detection thresholds were measured with captive manatees that were trained to detect the slightest shifts in the ambient noise using pure tones, broadband maskers and boat noise. Wild free-ranging manatees may not be as focused or "tuned in" as test sophisticated manatees. This said, a conservative estimate that wild manatees require a minimum of 10 dB above ambient conditions to hear approaching boat noise is an arguable assumption. They may require even higher levels above ambient. It is important to recognize that, whatever the CR values, they significantly affect the ability of manatees to hear as well as locate the sounds of approaching boats.

BOAT NOISE

The electric boat was routinely driven through the buoy field at each site to get baseline measurements of source levels as the boat passed each hydrophone as well as propagation data relative to the other buoys at each location. As noted earlier, two different engines were used. The rationale for an electric boat was an effort to isolate the reactions of manatees to the sounds of an outboard from the sounds of an alarm. It was believed that the sounds of an electric boat might be quieter than a gas engine. However, the RR engine had a relatively high gear reduction ratio (4:1) with a small 9" three blade propeller. This resulted in fast propeller tip rotations at relatively slow boat speeds which in turn produced higher frequencies and louder intensities than a typical gas outboard would at the same speeds. At speeds ≥ 3 mph the propeller tended to "sing" at 1.2 kHz and produced higher frequencies which manatees could hear at distances ≤ 20m. We did not use this engine for controlled approaches as it had an electrical failure and was shipped back to the manufacturer. However, before it failed we used the engine on site for field preparations. Manatees could hear the propeller singing and some became curious and followed the boat (Figure 11).

Figure 11. Manatees attracted to singing propeller.

The RR engine produced higher frequency sounds which some manatees avoided and others investigated. When manatees came too close the engine was shut off and we drifted until manatees lost interest or left. The spectrograph in Figure 12a illustrates the dominant tonal at 1.2 kHz and associated harmonic and sub harmonic banding at higher frequencies. The intensity of the spectra is plotted in Figure12b.

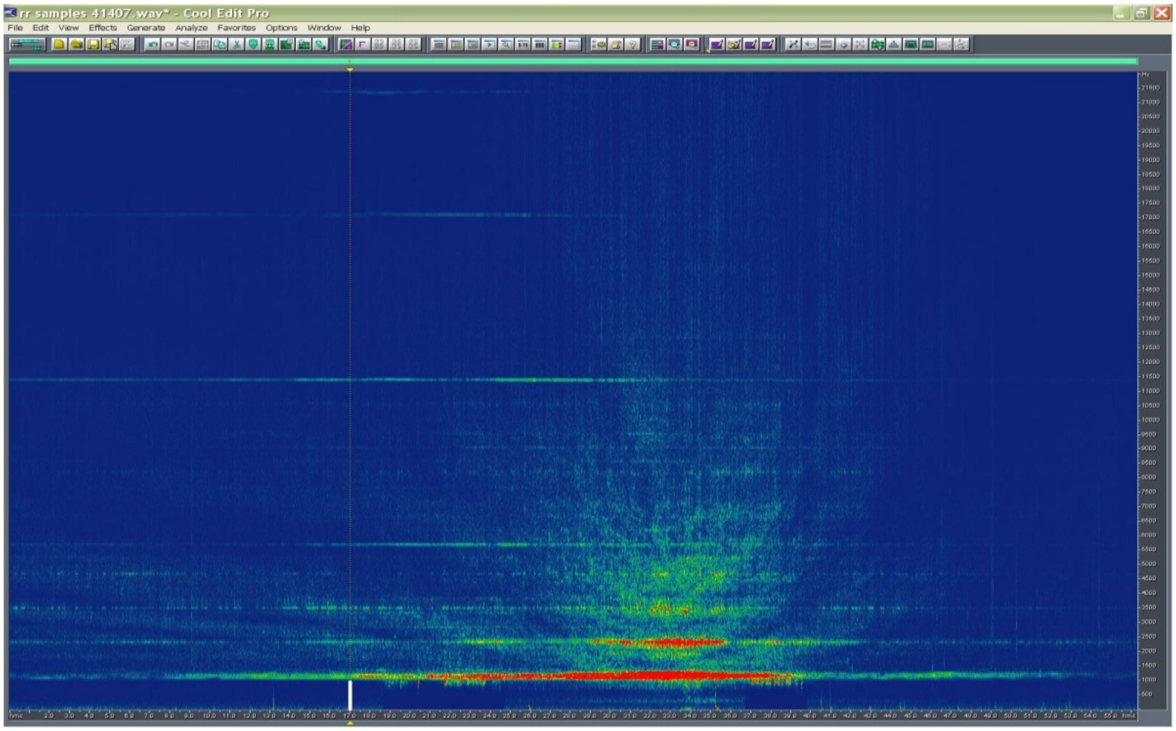

Figure 12a. Spectrogram of RR engine passing buoy at 3mph, note prop singing (PS) at 1.2 kHz.

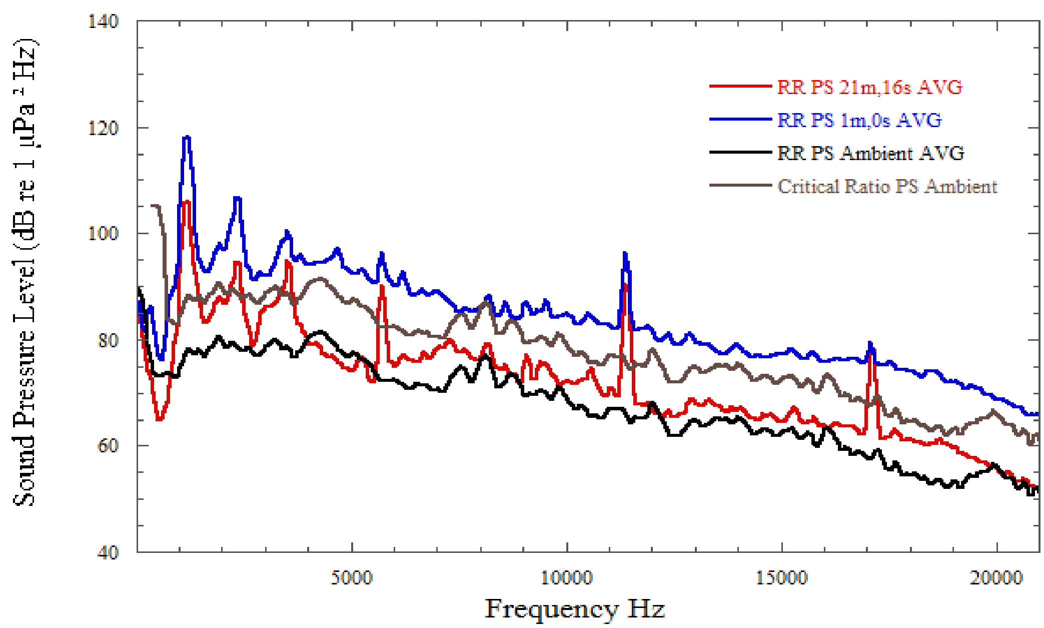

Figure 12b. Spectral Density Plot for boat with RR engine at 3mph. Plot selected 21 m (16s distance) and 1m (0s distance) from propeller to illustrate spectral and intensity levels.

The Ray replacement engine was used for the subsequent controlled approach runs. This engine was geared lower (2.6:1) which allowed for a larger 12 inch, two blade propeller. This produced lower blade rate harmonics and better approximated the sounds of a more typical gas engine. The sound of the Ray engine pushing the 6m pontoon at 4 mph approximated the sound from a 195 hp Johnson outboard with a 14" three blade propeller pushing a 6m deck boat at 4 mph (Figures 13a, 13b, 13c). To dampen the gear noise of the Ray engine we insulated the lower unit with closed cell neoprene. The series of figures compares the spectral density levels for the Ray electric and Johnson gas engines. The plots in these figures illustrate both averaged RMS and peak intensities for both engines as they approached a recording buoy. Figure 13a plots the sequential approach of the electric boat during an actual *no-alarm* trial (Run l9). This trial was conducted at White Point. The averaged ambient noise referenced was recorded minutes before this trial was conducted. Figure 13b plots a spectra of the Johnson engine past a buoy in the Indian River (no manatees present). Note that the critical ratio is reference against the White Point ambient condition. The CR represents the minimal energy necessary for a manatee to detect the noise against the prevailing ambient condition 50% of the time. The spectral lines capture 9m and 1m distances from the propellers. Nine meters is when the boat had to veer away when the focal manatee exhibited no reaction to the approach. Both the Peak (PK) levels and averaged (AVG) levels are presented. Averaged levels are more representative of the sound over time.

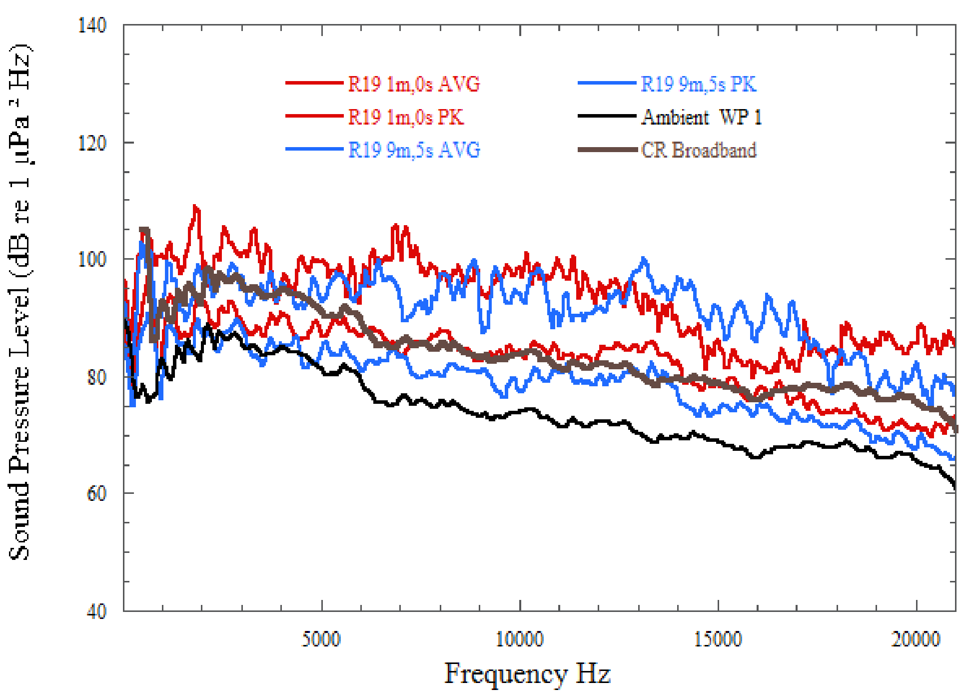

Figure 13a. Approach sequence for Run 19. Manatee did not respond as boat veered away at 9m distance.

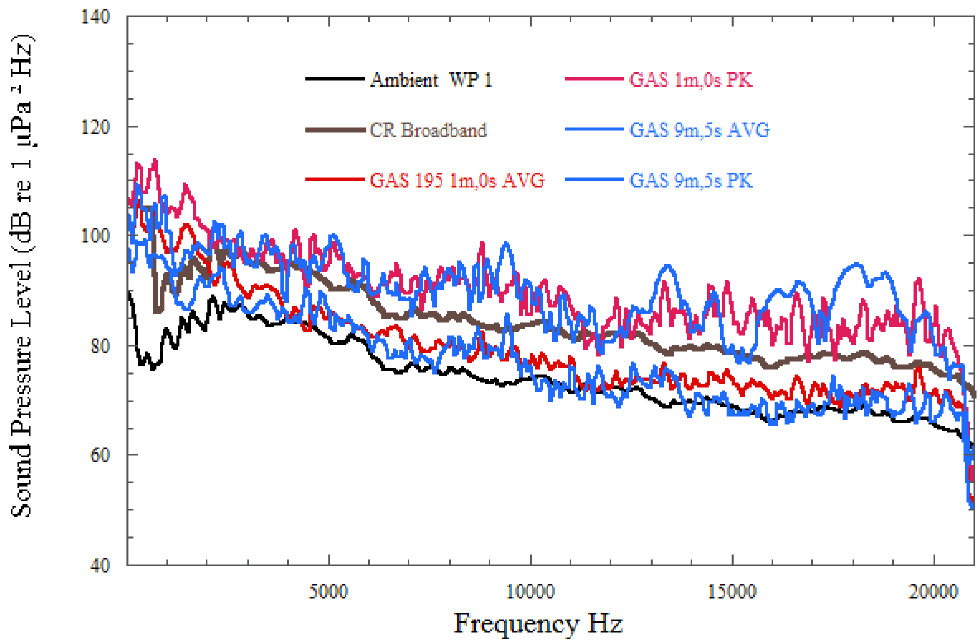

Figure 13b. Approach sequence of 6m boat traveling 4mph with a 195 hp gas outboard and ambient noise overlaid.

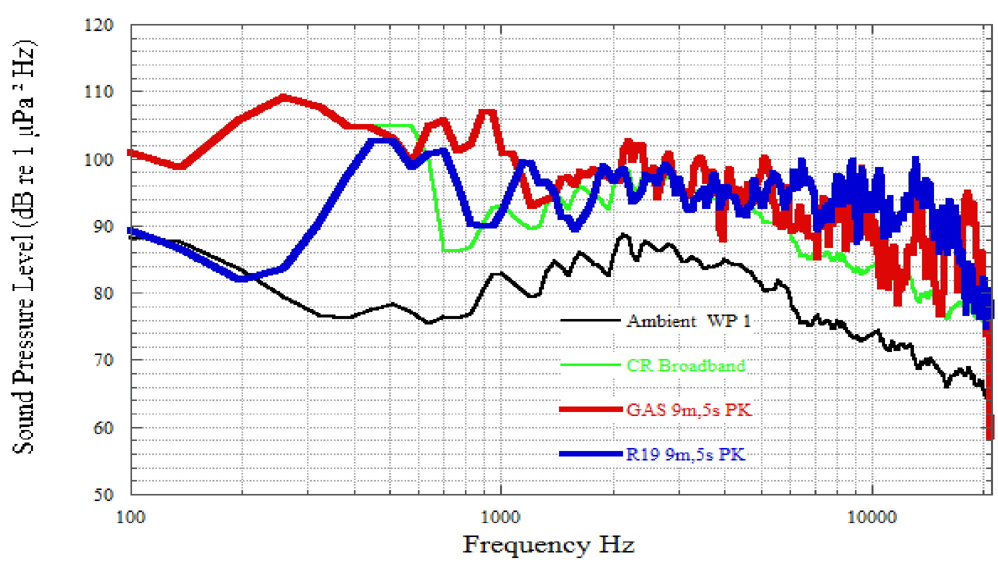

Figure 13c. Log scale view of gas and electric engines at 4mph.

While we managed to reduce some of the higher frequency spectra of the Ray engine and better approximate a typical outboard, the electric engine still emits more energy than a gas outboard at higher frequencies. Conversely, the Johnson engine emitted more energy at frequencies below 1 kHz. In shallow water habitats, the electric engine could be more detectable than the gas engine.

The spectrograms in Figures 14a and 14b show two different alarm configurations used for this study. One was an amplitude modulated tonal centered at 16 kHz and the other was a frequency modulated band from 10-20 kHz. Only six *alarm* trials were conducted this season. Three were the amplitude modulated signal in Figure 14a and three were the frequency modulated band in Figure 14b. Both alarm types elicited avoidance diving and swimming behaviors approximately 15-25m away. With such a small sample size we cannot infer any difference with respect to effectiveness between these two single types. Manatees responded at received signal levels ranging from 103-116 dB for both. Figures 15a and 15b illustrate the spectral intensities at the distances manatees reacted during controlled approaches with the alarm, as well as the noise of the boat as it passed the manatees' position.

The frequency spectra of both alarm signals were centered at 15 kHz so losses from shallow water low frequency cut-offs or Lloyd's Mirror effects did not affect propagation of the alarm signal. However, propagation losses from scattering as well as gains from reflection did have effects on signal level. Calibrated projection measurements through sea grass beds and rafts of floating grass resulted in losses ranging from 29–34dB at 50m. At times there were large mats of sea grass floating about and it was important to keep the face of the projector clear (Figure 16).

Naturally occurring ambient noise was dominated by snapping shrimp and the frequency spectra of shrimp noise overlapped with the device frequencies at 10 kHz to 20 kHz. The manatees' critical ratio for 1/3 octave noise centered at 15 kHz is 10 dB (Gerstein et al. 1994, 1996, 1997). Against a midpoint ambient level of 75dB the alarm needed to be at least 85dB re 1μPa for manatees to detect it 50% of the time. They responded at received levels ≥ 18 dB over their estimated critical ratios. The size and shape of the alarm's acoustic footprint was determined by the projector's highly directional 6° beam width. The forward projecting parametric field formed like a cone expanding in a direct line ahead of the boat. At 50m the diameter of the sound field expanded to ~ 6m, which was wider than the diameter calculated for the base of a cone; D = 2 x [H x tan (angle)] (angle of the isosceles triangle drawn 90° to the center of the base). At a 50m distance this is calculated as follows: D = 2 (50 x tan 3), D = 2 (50 x .052407779), D = 5.24m. The directivity of the device in the field was affected by scattering and reflection and it was monitored and measured from passes through the GPS instrumented buoy fields. The last controlled run of the season was an *alarm* run at the NASA causeway bridge area. The run is pictured on the cover of this report. As the focal animal dove 20m ahead of the approach boat, another manatee was caught on video heading directly toward the boat. This other manatee was 3m off axis from the center of the bow to the port side. At a 20m distance the field of the projector was only ~ 2.5m (beam width of the boat) and the approaching manatee was outside the projection field. The focal manatee that dove surfaced ~ 4m off the starboard side of the boat's path, returning to the buoy where it was when we began this *alarm* trial. For testing purposes the very narrow directivity poses no problem because we carefully line up with the focal animal, however, if the device were to be adopted as a protection tool in the future a wider beam width is advisable.

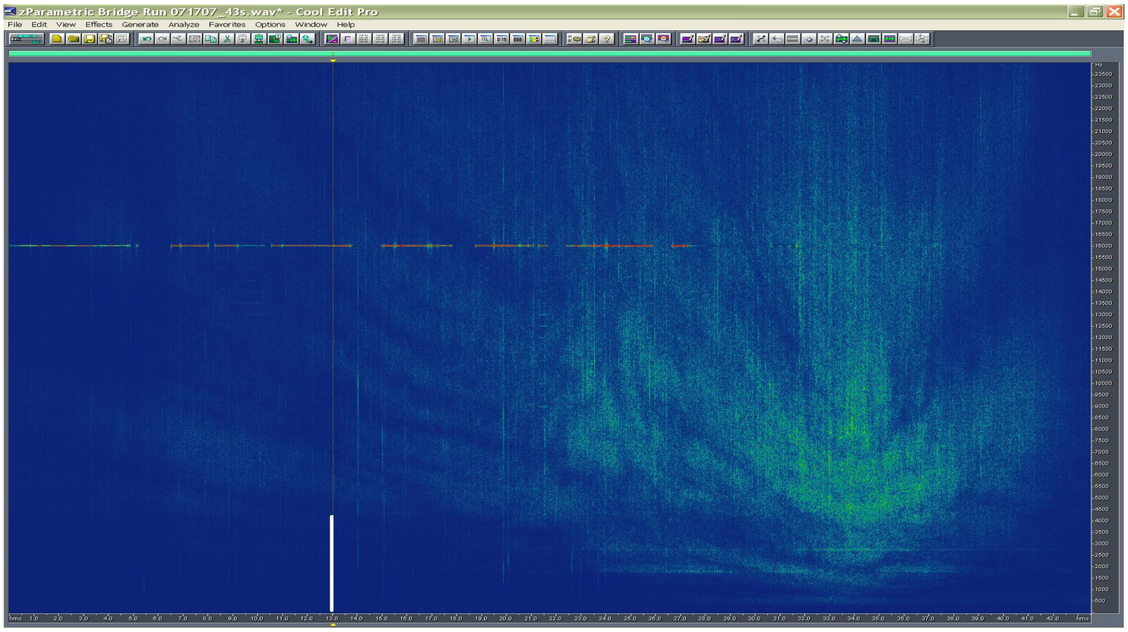

Figure 14a. Parametric amplitude modulated alarm centered at 15 kHz.

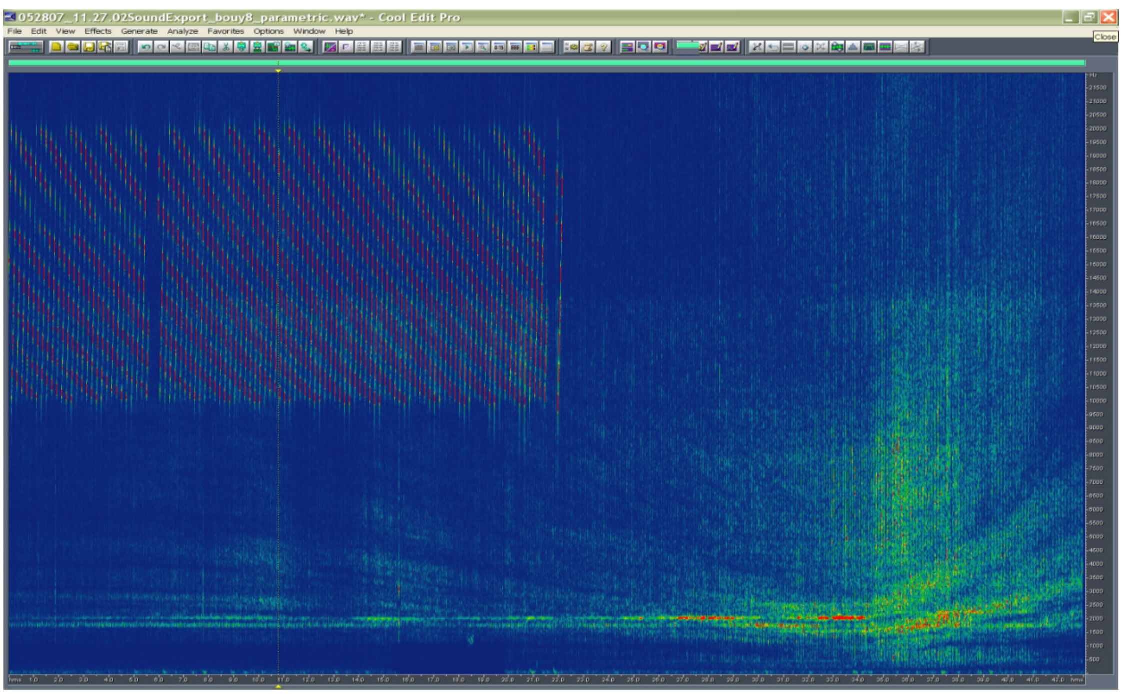

Figure 14b. Parametric frequency modulated band centered at 15 kHz.

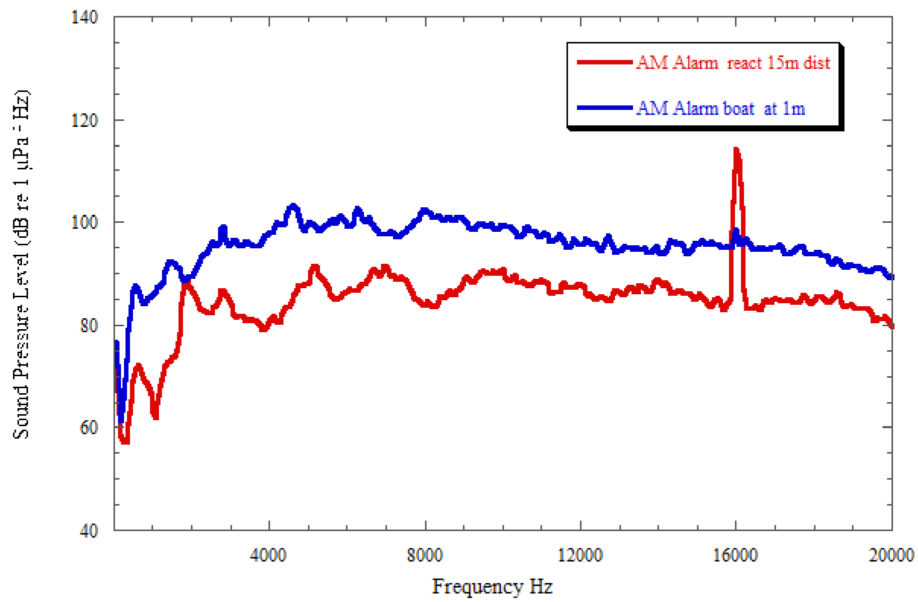

Figure 15a. Spectral plot parametric amplitude modulated alarm centered at 15 kHz.

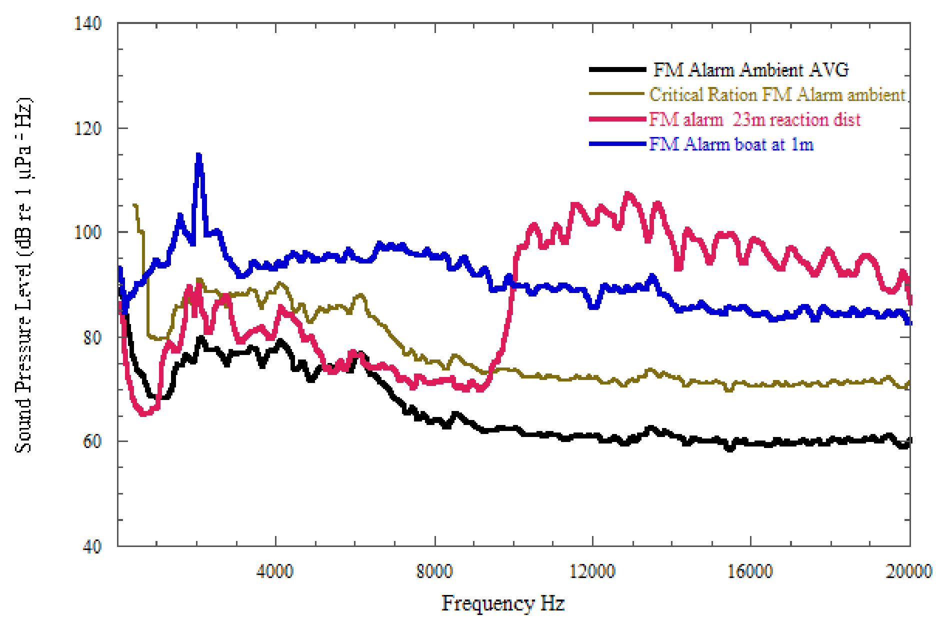

Figure 15b. Spectral plot of parametric frequency modulated band centered at 15 kHz.

Figure 16. Setting a reference buoy for propagation measurements through sea grass mats and beds. Parametric and J-9 projectors were positioned at the middle of bow with the attachment poles seen here at the bow.

PRELIMINARY RESULTS AND DISCUSSION

Site-specific bathymetry and acoustical data, along with behavioral observations on manatees, were collected over 45 days from April 1 until July 17, 2007. Controlled boat approach trials were only conducted when water visibility was clear enough to view focal animals and track their position and behavior throughout approach sequences. Unseasonably high sustained winds from March through June reduced visibility and minimized the number of days controlled boat trials could be attempted. Trials were conducted over 11 days. A total of forty-nine controlled boat trials were successfully completed. Forty-three (88%) of these were *no-alarm* trials and six (12%) were *alarm* trials. Eight boat approach attempts were aborted when we lost sight of the focal animal. The dates, times, locations, focal individuals, boat speed, approach distances, depth, field conditions, and behavioral observations along with referenced incidents of Type B harassment are presented in Table I. Summary statistics across behavior and conditions with respect to the *alarm* or *no-alarm* conditions are presented in Appendix A.

Seven percent (7%), only three of the forty-three, *no-alarm* approach trials resulted in a measurable avoidance reaction, or change in behavior. The remaining ninety-three percent (93%) of *no-alarm* trials resulted in no change in behavior from focal manatees until the boat came within ≤8m (approximately 3 manatee body lengths) and veered away.

Table I

In contrast, one hundred percent (100%), six of six *alarm* trials elicited overt avoidance responses (a change from resting or feeding to swimming away or diving). These changes were exhibited at ranges of 15 - 25m ahead of the bow. The mean response change in behavior was significantly greater during *alarm* trials (F=76.74, df=1, p< 0.01). The mean distance at which focal manatees responded was also significantly greater during *alarm* trials (F= 143.42, df=1, p< 0.01). These differences are tabulated in Table II and illustrated further in Figures 17a and 17b.

Table II.

CHANGE OR NO CHANGE IN BEHAVIOR DURING BOAT APPROACHES

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
NO ALARM	43	6.977E-02	.2578	3.931E-02	-9.5623E-03	.1491	.00	1.00
ALARM	6	1.0000	.0000	.0000	1.0000	1.0000	1.00	1.00
Total	49	.1837	.3912	5.589E-02	7.130E-02	.2960	.00	1.00

DISTANCE (m) AT WHICH A CHANGE OF BEHAVIOR OBSERVED

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
NO ALARM	43	6.5814	2.0957	.3196	5.9364	7.2264	3.00	13.00
ALARM	6	19.1667	4.2151	1.7208	14.7432	23.5901	15.00	25.00
Total	49	8.1224	4.8029	.6861	6.7429	9.5020	3.00	25.00

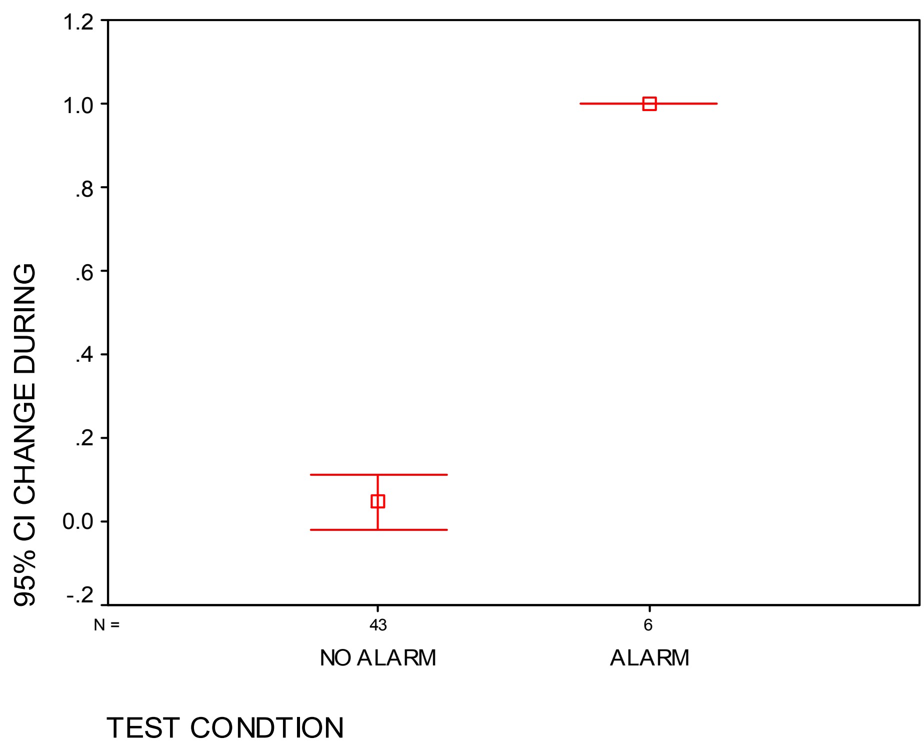

Figure 17a. Error plot illustrating the different response results for *no-alarm* and *alarm* conditions.

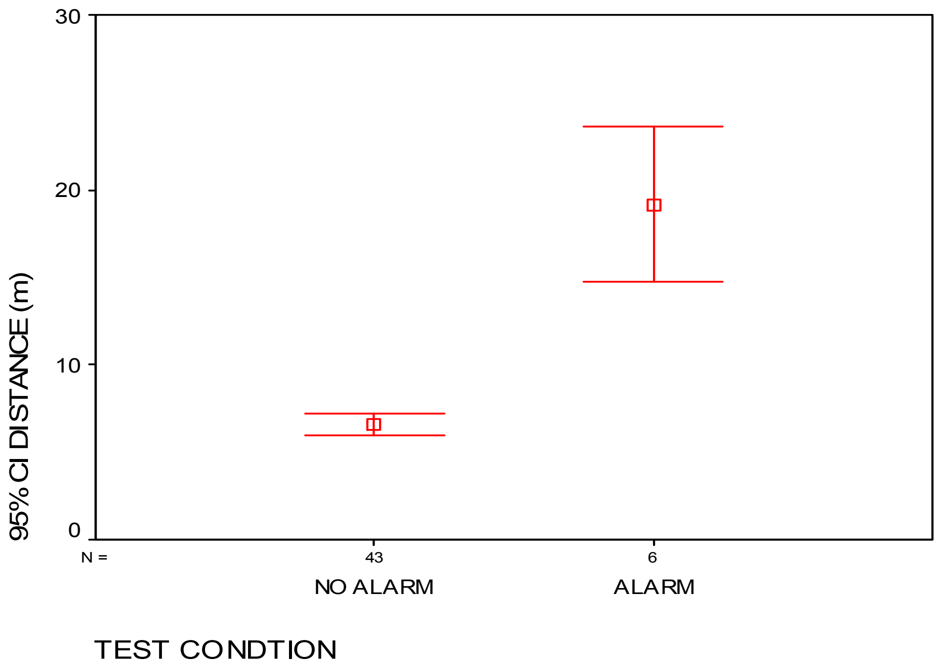

Figure 17b. Error plot illustrating the different mean distances at which the focal manatees respond**.**

Behavioral observations were segregated into three general time categories: (1) behavior before initiating the approach, (2) behavior during the approach and (3) behavior at or within three body lengths, when the boat veered away or passed the focal manatee. Video segments of the completed experimental approach trials and control periods (*behavior before, and/or a minimum of 30 minutes after a trial*) were created for behavioral scoring using Adobe Premier Professional. The videos during control and experiential trials were reviewed and scored by two researchers independent of each other. Video segments were provided without the acoustic tracks and viewed on a 24 inch flat screen HD monitor. The presenter and reviewers did not know when *alarm* or *no-alarm* segments were being scored. This double blind was used to minimize scoring bias. GPS time, boat speed and buoy coordinates were available for accurately scaling distances. The videos were also time-coded for scoring reference and to further facilitate accurate distance determinations between the focal manatee and the approaching boat. After videos were scored, their synchronized audio tracks were turned on to measure the acoustic spectra and levels associated with time referenced behavioral scores. In an effort to afford some continuity we selected similar behavioral categories as Nowacek et al. (2004) had in their previous study of wild manatees and boats near Sarasota, Florida. We recorded and noted changes in five general categories: (1) *Resting* (or mobility), (2) *Feeding,* (3) *Orientation* (or heading), (4) *Swimming* (or change in swimming speed), (5) *Diving* (or distance from the surface). Within categories 3, 4, and 5 the direction of change was indicated e.g., *toward the boat, away from the boat,* or *toward a channel or hole*.

The selection of these categories and subsequent behavioral observations are biased by the prerequisites we established for selecting focal manatees. Targeted focal animals were only approached after they had settled inside the buoy field and we could reliably track and/or identify them. Animals that were swimming quickly and transecting through the area were not targeted. Focal animals tended to be alone, and resting, or feeding in the proximity of a numbered recording buoy. The limited distribution of behaviors are shown in the BEFORE plot below in Figure 18a. Pre-selection conditions were adopted to insure we had a visual and acoustical "lock" on the focal animal. The result of such filtering is that the pool of animals exhibit more sedentary behaviors that may be more resistant to change. As a condition of our permit we made an effort to select isolated individuals and therefore did not measure changes in distance between individuals. The selection bias influenced the evaluations of control selections as social interactions during control periods resulted in more behavioral variability than was observed during the *no-alarm* trials.

The most predominant effect during *no-alarm* trial approaches was no response. When the boat was veering away and/or passing, behavioral changes increased, and are illustrated in the different behaviors and frequencies plotted for the different periods in Figure 18b and 18c. The change in behaviors and frequencies of behaviors were significantly higher during veering and passing conditions (t- statistic = 3.286, $p<0.05$).

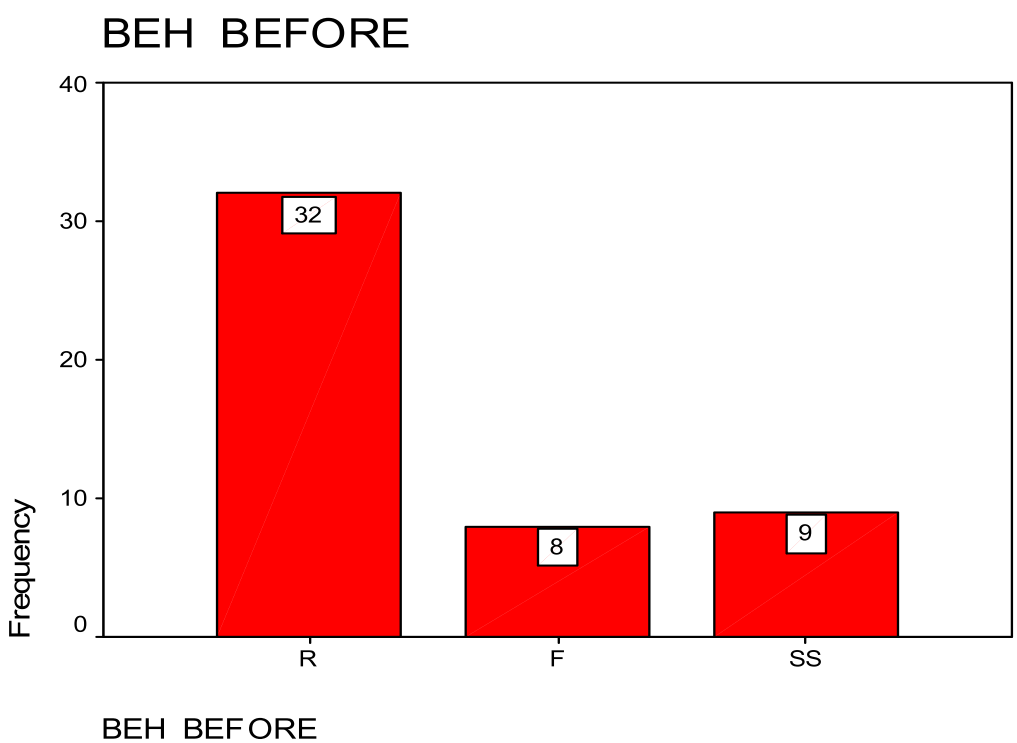

Figure 18a. Distribution of behaviors exhibited by focal manatees prior to approaches.

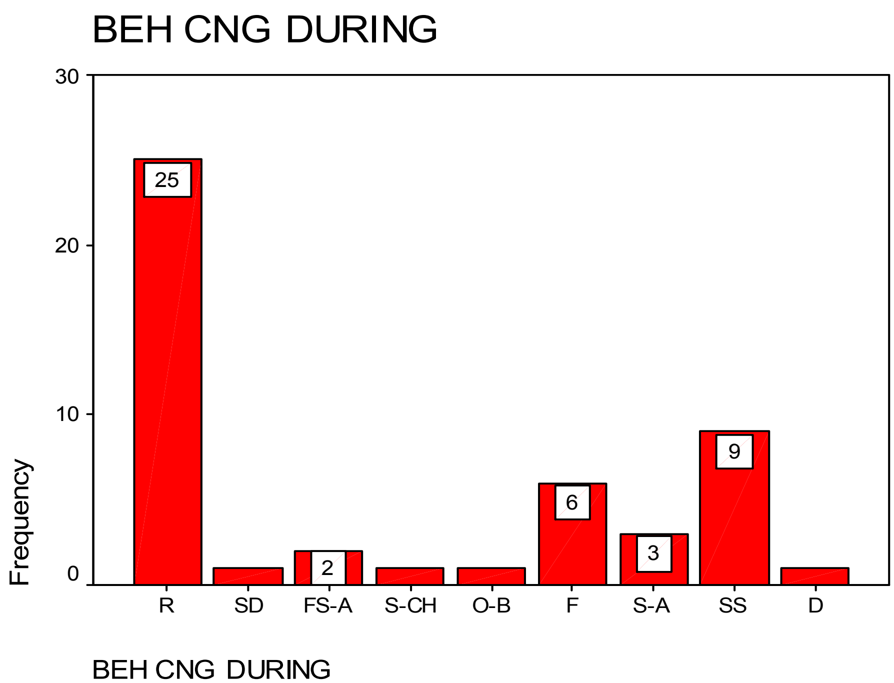

Figure 18b. Change in behaviors and frequencies during approach trials.

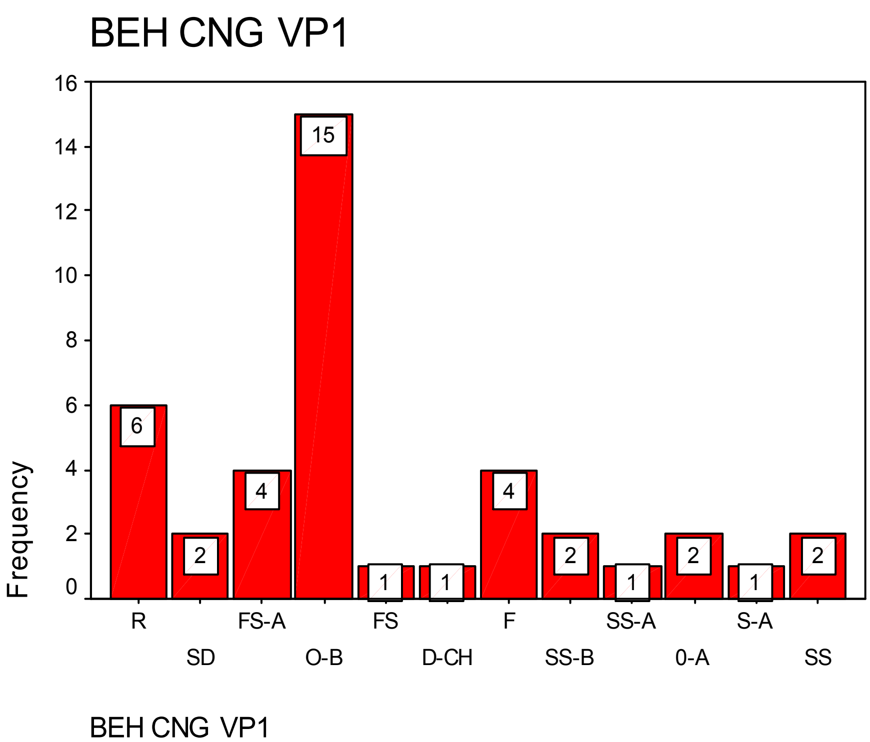

Figure 18c. Change in behaviors and frequencies during veering and passing.

Twenty five manatees were approached in this season. The frequency and types of approaches are illustrated in Figure 19. Many of the individuals in the MINWR were scared from previous boat encounters so they were not naive to boats. Six alarm trials were run with six different focal manatees. Five (5) identified manatees had previously been approached under the *no-alarm* condition and did not respond until the boat passed or veered away. These trial-experienced manatees exhibited overt avoidance responses (diving and swimming away) to the boat approaches with the alarm activated at distances ranging from15-25m from the approach boat. One of these individuals was approached two different times under the *no-alarm* condition and once under the *alarm* condition. This focal animal responded to the alarm and did not respond to either of the *no-alarm* approaches. One unknown naive manatee was approached under the *alarm* condition and dove away 25m from the approaching boat.

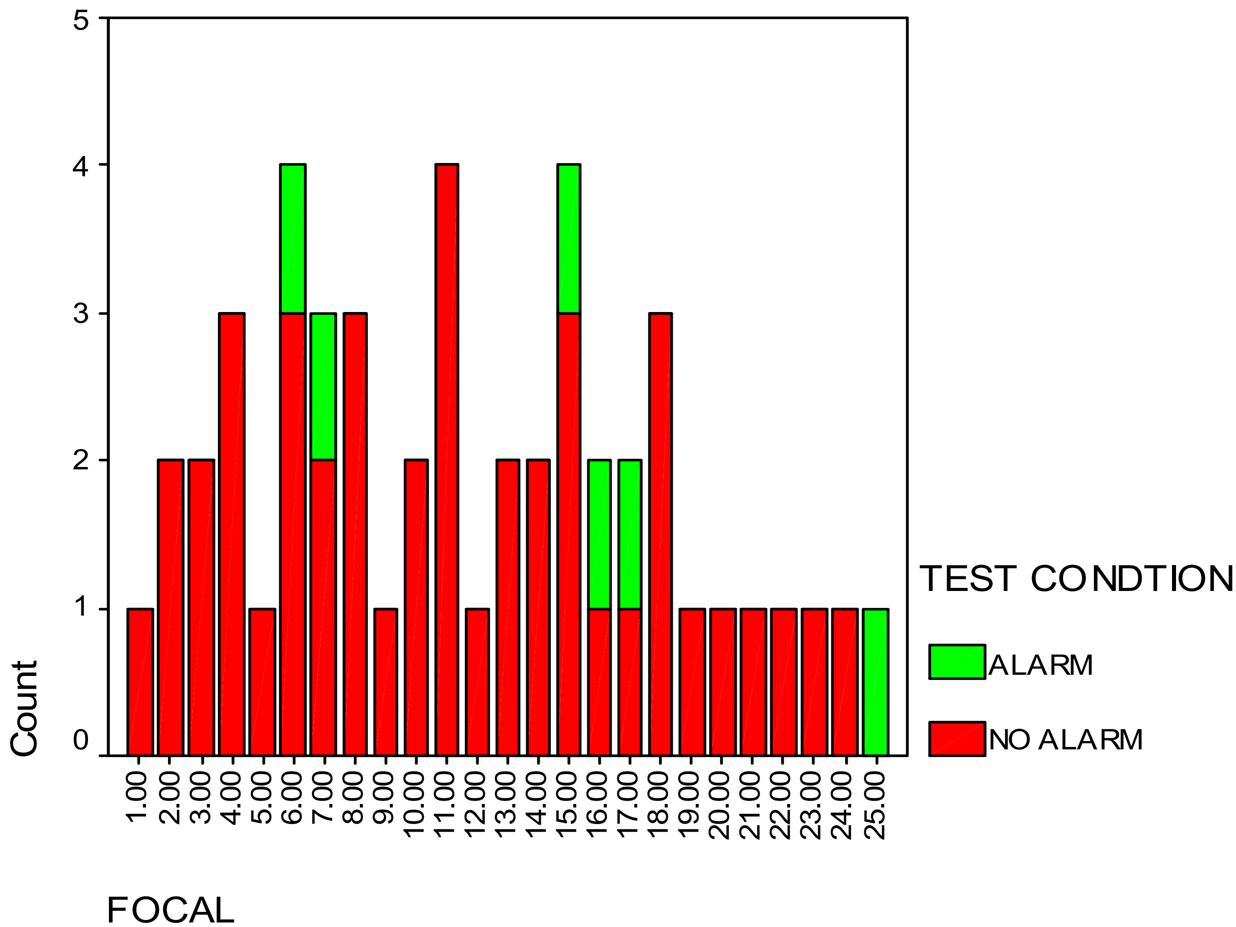

Figure 19. Number of trials and condition for each focal manatee.

While 100% of the six *alarm* trials resulted in significant increases in the distance where avoidance behaviors occurred (swimming away from boat and diving), statistical inference regarding the efficacy of the technology has limited power with the small sample size. However, the observation of forty of forty-three *no-alarm* trials resulting in no reactions to *no-alarm* trials is important with respect to better understanding of the boater–manatee interaction problem. Tests repeated with typical power boat configurations need to be conducted with the alarm. Many of the individuals in the MINWR were scared from previous boat encounters so they were not naive to boats. However the unique signature of the boat and context of interactions in the specific site are factors which could have influenced manatee behavior. More measurable causes for manatees not responding are high ambient levels from snapping shrimp, propagation limits of the shallow water, Lloyd's mirror losses near the surface and the low source levels of the slow boat approaches. These acoustical factors directly determined the distances at which boat noise was audible. Of the *no-alarm* trials, 93% resulted in no change until the boat was veering away or passing at 3 body length distances. Calibrated measurements at focal animal locations demonstrate received acoustic levels equal to or below manatee critical ratios for broad band noise. Some manatees appeared to be startled when the boat changed heading and veered away or passed them. At distances ≤ 8m manatees were capable of hearing and seeing the boat. At near field distances ~ 2m away they could have also felt the boat as it veered and/or passed For animals that exhibited no reactions as the boat passed, behavioral states and motivational factors eclipse acoustical and other sensory processes as determinates of behavior. However, for the majority individuals that responded as the boat veered off or passed, their unresponsiveness during the approach could have been mediated by acoustical factors alone. Gerstein et al. (1994, 1995) first proposed that shallow water and near surface propagation effects along with the manatees' unique auditory constraints made them vulnerable to repeated collisions with watercraft. They were the first to measure and detail acoustical transmission loss and boat noise propagation in several manatee habitats (Gerstein and Blue 1996, 1997). They also measured hearing and critical ratios for pure tones and broad band noise (Gerstein et al., 1994, 1996, 1997, 1999) and argued that shallow water propagation limits and Lloyd's mirror effect shaped manatee hearing and that these physical parameters together with the manatees' unique auditory constraints placed them at a sensory disadvantage for detecting and locating the dominant low frequency sounds of motor boats. Nowacek et al. (2004) reported that 47% of the animals they observed exhibited no reaction to approaching boats. Though they did not directly measure acoustical parameters at the time, the authors considered the plausibility that shallow water propagation factors along with masking contribute to the problem by interfering with manatees' ability to detect and locate the sounds of approaching boats. The behavioral results and accompanying acoustical measurements indicate that manatees do not detect the sounds until the boat is very close and in the process of veering away or passing at distance ≤8m. These results are inconsistent with observations of manatees responding to slow gas outboards at distances of 25-50m (Nowacek et al. 2005). Many factors including boat types and propagation properties could account for these differences. Both studies observed increased responses with increased proximity. Manatee swimming speeds increased in shallower habitats when boat approaches were within ≤ 9m (Nowacek et al. 2005). Shallow water habitat constraints, as well as the proximity and increased sensory awareness, could have intensified these reactions. The same can be extended to the significant increase we observed in behavioral reactions at distances ≤ 8m. Continual calibrated measurements at focal animal locations revealed that averaged boat noise fell below estimated critical ratios at received distances ≥ 9m. As distance decreased, boat approaches became more audible. Milkis–Olds and Miller 2006 measured transmission loss in various manatee habitats and applied a Monterey-Miami parabolic equation model which further confirmed that the manatees' shallow water habitat does indeed limit the dominant spectra of slow moving boats and that low frequency propagation was inefficient below 2 kHz which Gerstein (1995) first suggested as the idealized cut-off frequency for typical manatee habitats.

HARASSMENT

Limiting our efforts to optimal field conditions resulted in our ability to reliably identify and track manatees in an area. Our activities did not displace any individual from resting or feeding areas, which further added to our success in tracking individuals throughout a day at a particular location. Slow boat approaches had little effect on manatee movements throughout the site. Harassment is defined as any measurable change our activities had on manatee behavior. It could be argued that for some changes, such as approaching and then following the boat, our presence was more a source of curiosity and entertainment than harassment. Table I references each harassment incident from controlled approaches into four levels: (1) *no harassment*, (2) *low level*, (3) *medium level* and (4) *high level harassment*. *No harassment* is defined within as no observable change in the animal's behavior. *Low level* is defined as a subtle change that did not involuntarily displace the individual (manatees that voluntarily investigated the boat or reoriented to look at the boat would fall into this category). *Medium level harassment* is defined as a slow response, such as a slow swim away or a slow dive, that temporarily displaced an individual, but in which the animal resumed its position and/or activity after the boat passed. *High level harassment* is defined as causing an abrupt or rapid change in behavior that displaced the manatee such as a fast swim away or dive.

Twenty-seven noted instances of harassment are listed in Table I and illustrated in Figure 20. Six instances of high level harassment are denoted where a focal manatee was temporarily displaced and/or reacted quickly as the boat approached or passed. Nine instances of medium level and eleven low level interactions are also listed.

The most explosive harassment incident of the season was caused by a seagull that startled a group of fourteen manatees that were peaceably eating sea grass clippings along the bank in 0.5-2m of water. The bird harassed more manatees in a single encounter than we had over most of the season (Figure 21).

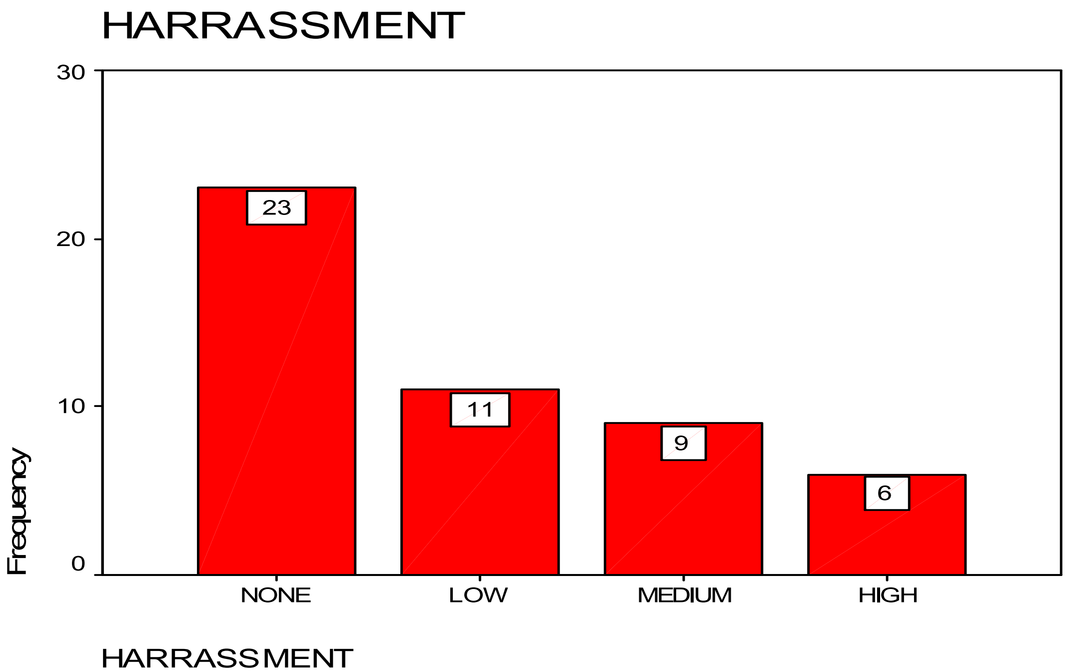

Figure 20. Incidents of harassment identified in Table I.

Figure 21. Manatees startled by a diving seagull.

RATIONALE FOR PROGRESSING TO PHASE II

Our most immediate recommendation and request is that the USFWS Division of Management Authority grant us permission to progress to Phase II. In the interest of time, we are not requesting any amendments or actions which require outside review prior to approval for Phase II activities.

The first objective of Phase I was to establish, test and refine site-specific field methodologies that provide reliable tools and protocols for observing manatee behavior and identifying individuals at the site. We have benefited from the expertise and the robust experience of individuals who have been studying the population in the Banana River. We have coordinated our activities through the MINWR and Dynamac Corporation and successfully conducted photo-identifications in consultation with Cathy Beck at the U.S. Geological Survey Sirenia Project. During the 2007 season we established strong lines of communication and effective on-site coordination within the KSC. The research effort has and should continue to benefit from the logistic support and facilitation we have received from MINWR, Dynamac and NASA officials. We are returning with the same experienced crew and we have additional technical support from the Navy as well as new collaborative efforts with software specialists at Cornell University. This assistance will help us batch process and integrate large acoustical records from our network of GPS instrumented buoys. After the first season we contend that our field activities have had a negligible impact on the habitat and posed minimal risks of injury or negative impacts on the manatee population. Progressing to Phase II would offer broader opportunities to better understand manatee interactions with typical boats and noise. Phase II, like Phase I, poses minimal negative impacts with opportunities for significant conservation benefits for the manatee population.

The second objective of Phase I and rationale for using an electric boat was to try and parse out the effects of boat noise versus alarm sounds with minimal risks to manatees. Observations of manatees not responding to the sounds of the approaching electric boat in this habitat were significant. Analysis of received acoustic levels during approach trials provided direct calibrated evidence that these sounds fell below the manatees' critical ratios for detection, or their thresholds of responding, at distances ≤ 9m. Acoustical propagation measurements and the significant difference in manatee behavior during *alarm* and *no-alarm* approaches provided evidence that it was the alarm sound alone which caused a differential effect on the distance at which associated avoidance behaviors were exhibited. Manatees that had previously not responded during *no-alarm* trials all responded at significantly longer distances, and with avoidance responses, during *alarm* trials with the same boat and electric engine. Though effective, the alarm also has limited range and high directivity which minimizes its potential to impact non-targeted individuals.

Prior to conducting these experiments it was uncertain how manatees might respond to alarm signals and there were concerns that manatees could be attracted to the alarm. Though manatees at times seemed attracted to singing propeller noise, they swam or dove away from the alarm and did not exhibit any attraction to the sound. The alarm proved to be effective at eliciting an avoidance response and did not attract manatees. It did not permanently displace manatees from their locations and/or prior activities. These are positive and encouraging results. We need to progress to testing this technology with typical outboards and boats in the same environment. Trials with typical boat outboard configurations are necessary to better evaluate real world encounters. Though we tried to approximate the condition acoustically with an electric boat; propeller tip rotations and associated gear noise is still too high to duplicate the sounds of gas engines which are geared lower. Conducting the same protocols in the same location with a typical gas outboard offers the opportunity for direct comparisons.

The logistics of operating the electric boat limits productivity and time on the water and there were also some drawbacks for continuing with an electric boat. The boat produces an electromagnetic field that occasionally causes unwanted electric interference with video recording and monitors. The electric boat is also underpowered and there are instances when the weather changes dramatically and we need to return to the dock to avoid lightning storms. Even with a gas kicker engine at the stern, facing strong headwinds, our maximum speed was 6 mph. With a strong electrical field and high tower we are an excellent lightning rod. The electric boat being underpowered is not always responsive enough to veer away from manatees that come too close. There were several instances when we needed to turn off the engine because we lacked the maneuverability to avoid an animal. Finally, when configured with a propeller guard, and operated at slow speed, both gas and electric powered boats pose minimal risks to manatees. However, a gas powered vessel does offer additional power and greater maneuverability to avoid manatees that swim or dive into the boat's path.

We respectfully request the permission to progress to Phase II as specified in permit MA063561 to better approximate real world encounters with typical boats and their associated noise signatures in shallow water habitats.

ACKNOWLEDGEMENTS

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Appendix A

Appendix A

Summarize

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
DISTANCE (m) * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
CHANGE DURING * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
BEH BEFORE * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
BEH CNG DURING * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
BEH CNG VP1 * TEST CONDTION	41	83.7%	8	16.3%	49	100.0%
BEH CHG V/P2 * TEST CONDTION	11	22.4%	38	77.6%	49	100.0%
CHANGE VEERING /PASSING * TEST CONDTION	41	83.7%	8	16.3%	49	100.0%
DEPTH (FT) * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
SPEED * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
TEMP (F) * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
FOCAL * TEST CONDTION	49	100.0%	0	.0%	49	100.0%
HARRASSMENT * TEST CONDTION	49	100.0%	0	.0%	49	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

			DISTANCE (m)	CHANGE DURING	BEH BEFORE
TEST CONDTION	NO ALARM	1	4.00	NO	R
		2	5.00	NO	SS
		3	6.00	NO	R
		4	8.00	NO	SS
		5	6.00	NO	SS
		6	10.00	YES	F
		7	13.00	YES	R
		8	6.00	NO	R
		9	6.00	NO	SS
		10	4.00	NO	R
		11	8.00	NO	R
		12	7.00	NO	SS
		13	7.00	NO	R
		14	7.00	NO	R
		15	6.00	NO	R
		16	13.00	YES	R
		17	6.00	NO	R
		18	6.00	NO	R
		19	8.00	NO	R
		20	7.00	NO	SS
		21	7.00	NO	R
		22	7.00	NO	R
		23	7.00	NO	SS
		24	5.00	NO	SS
		25	6.00	NO	R
		26	8.00	NO	F
		27	3.00	NO	R
		28	8.00	NO	F
		29	7.00	NO	R
		30	4.00	NO	R
		31	6.00	NO	F
		32	5.00	NO	R
		33	7.00	NO	R
		34	7.00	NO	SS
		35	7.00	NO	F
		36	7.00	NO	R
		37	4.00	NO	R
		38	4.00	NO	R
		39	5.00	NO	F
		40	6.00	NO	R
		41	10.00	NO	F
		42	6.00	NO	R
		43	4.00	NO	R

Case Summaries[a]

				DISTANCE (m)	CHANGE DURING	BEH BEFORE
TEST CONDTION	NO ALARM	Total	N	43	43	43
			Mean	6.5814	6.977E-02	3.6512
			Median	6.0000	.0000	.0000
			Grouped Median	6.4348	6.977E-02	3.2941
			Std. Error of Mean	.3196	3.931E-02	.7682
			Sum	283.00	3.00	157.00
			Minimum	3.00	NO	R
			Maximum	13.00	YES	SS
			Range	10.00	1.00	12.00
			Std. Deviation	2.0957	.2578	5.0374
			Variance	4.392	6.645E-02	25.375
			Kurtosis	2.676	10.755	-1.119
			Std. Error of Kurtosis	.709	.709	.709
			Skewness	1.239	3.501	.818
			Std. Error of Skewness	.361	.361	.361
	ALARM	1		23.00	YES	R
		2		15.00	YES	R
		3		17.00	YES	R
		4		20.00	YES	R
		5		15.00	YES	F
		6		25.00	YES	R
		Total	N	6	6	6
			Mean	19.1667	1.0000	1.1667
			Median	18.5000	1.0000	.0000
			Grouped Median	18.5000	1.0000	1.1667
			Std. Error of Mean	1.7208	.0000	1.1667
			Sum	115.00	6.00	7.00
			Minimum	15.00	YES	R
			Maximum	25.00	YES	F
			Range	10.00	.00	7.00
			Std. Deviation	4.2151	.0000	2.8577
			Variance	17.767	.000	8.167
			Kurtosis	-1.817	.	6.000
			Std. Error of Kurtosis	1.741	.	1.741
			Skewness	.403	.	2.449
			Std. Error of Skewness	.845	.	.845
	Total	N		49	49	49
		Mean		8.1224	.1837	3.3469
		Median		7.0000	.0000	.0000
		Grouped Median		6.6957	.1837	2.9750
		Std. Error of Mean		.6861	5.589E-02	.6959
		Sum		398.00	9.00	164.00
		Minimum		3.00	NO	R
		Maximum		25.00	YES	SS
		Range		22.00	1.00	12.00
		Std. Deviation		4.8029	.3912	4.8715
		Variance		23.068	.153	23.731
		Kurtosis		4.120	.876	-.854
		Std. Error of Kurtosis		.668	.668	.668
		Skewness		2.073	1.686	.943
		Std. Error of Skewness		.340	.340	.340

Case Summaries[a]

			BEH CNG DURING	BEH CNG VP1	BEH CHG V/P2
TEST CONDTION	NO ALARM	1	R	O-B	.
		2	SS	SS-B	.
		3	R	FS-A	.
		4	SS	O-B	.
		5	SS	FS-A	.
		6	O-B	SS-B	.
		7	SD	.	.
		8	R	SD	.
		9	SS	SS	.
		10	R	S-A	.
		11	R	SS	.
		12	SS	FS-A	.
		13	R	R	.
		14	R	O-B	.
		15	R	R	.
		16	S-CH	.	.
		17	R	O-B	.
		18	R	SS-A	.
		19	R	R	.
		20	SS	SD	.
		21	R	R	.
		22	R	FS-A	.
		23	SS	O-B	SS-B
		24	SS	O-B	.
		25	R	O-B	SS-A
		26	F	F	.
		27	R	O-B	.
		28	F	F	.
		29	R	O-B	SS-B
		30	R	D-CH	S-B
		31	F	F	.
		32	R	O-B	SS-A
		33	R	R	.
		34	SS	FS	0-B
		35	F	F	.
		36	R	0-A	S-A
		37	R	O-B	.
		38	R	R	.
		39	F	0-A	S-A
		40	R	O-B	S-B
		41	F	O-B	.
		42	R	O-B	S-B
		43	R	O-B	S-B

Case Summaries[a]

				BEH CNG DURING	BEH CNG VP1	BEH CHG V/P2
TEST CONDTION	NO ALARM	Total	N	43	41	11
			Mean	3.6744	4.6098	10.1818
			Median	.0000	4.0000	11.0000
			Grouped Median	.6923	4.1250	10.5000
			Std. Error of Mean	.7572	.5306	.8720
			Sum	158.00	189.00	112.00
			Minimum	R	R	0-B
			Maximum	SS	SS	S-B
			Range	12.00	12.00	9.00
			Std. Deviation	4.9652	3.3976	2.8920
			Variance	24.653	11.544	8.364
			Kurtosis	-1.031	-.334	.453
			Std. Error of Kurtosis	.709	.724	1.279
			Skewness	.848	.566	-.857
			Std. Error of Skewness	.361	.369	.661
	ALARM	1		S-A	.	.
		2		S-A	.	.
		3		S-A	.	.
		4		FS-A	.	.
		5		FS-A	.	.
		6		D	.	.
		Total	N	6		
			Mean	8.5000		
			Median	11.0000		
			Grouped Median	9.2000		
			Std. Error of Mean	2.1095		
			Sum	51.00		
			Minimum	FS-A		
			Maximum	D		
			Range	12.00		
			Std. Deviation	5.1672		
			Variance	26.700		
			Kurtosis	-1.731		
			Std. Error of Kurtosis	1.741		
			Skewness	-.731		
			Std. Error of Skewness	.845		
	Total	N		49	41	11
		Mean		4.2653	4.6098	10.1818
		Median		.0000	4.0000	11.0000
		Grouped Median		.9231	4.1250	10.5000
		Std. Error of Mean		.7410	.5306	.8720
		Sum		209.00	189.00	112.00
		Minimum		R	R	0-B
		Maximum		D	SS	S-B
		Range		14.00	12.00	9.00
		Std. Deviation		5.1872	3.3976	2.8920
		Variance		26.907	11.544	8.364
		Kurtosis		-1.366	-.334	.453
		Std. Error of Kurtosis		.668	.724	1.279
		Skewness		.642	.566	-.857
		Std. Error of Skewness		.340	.369	.661

Case Summaries[a]

			CHANGE VEERING /PASSING	DEPTH (FT)	SPEED
TEST CONDTION	NO ALARM	1	YES	5.50	2.00
		2	YES	5.50	2.00
		3	YES	5.40	3.00
		4	YES	5.80	4.00
		5	YES	6.30	4.00
		6	.	6.30	3.00
		7	.	23.70	3.00
		8	YES	23.70	4.00
		9	NO	8.20	3.00
		10	YES	6.90	3.00
		11	YES	8.20	4.00
		12	YES	5.70	3.00
		13	NO	13.40	3.00
		14	YES	23.80	3.00
		15	NO	5.40	3.00
		16	NO	5.70	4.00
		17	YES	8.20	3.00
		18	YES	8.20	3.00
		19	NO	19.40	3.00
		20	YES	24.80	3.00
		21	NO	20.40	4.00
		22	YES	23.60	3.00
		23	YES	16.80	3.00
		24	YES	16.60	4.00
		25	YES	8.00	4.00
		26	NO	9.10	4.00
		27	YES	8.00	4.00
		28	NO	12.20	3.00
		29	YES	9.20	3.00
		30	YES	6.30	2.00
		31	NO	8.80	3.00
		32	YES	8.80	3.00
		33	NO	6.40	3.00
		34	YES	13.70	2.00
		35	NO	6.00	4.00
		36	YES	8.10	2.00
		37	YES	8.10	2.00
		38	NO	8.40	3.00
		39	YES	8.00	3.00
		40	YES	8.00	3.00
		41	YES	8.00	4.00
		42	YES	6.20	3.00
		43	YES	6.00	3.00

Case Summaries[a]

				CHANGE VEERING /PASSING	DEPTH (FT)	SPEED
TEST CONDTION	NO ALARM	Total	N	41	43	43
			Mean	.7073	10.5767	3.1395
			Median	1.0000	8.1000	3.0000
			Grouped Median	.7073	8.1167	3.1622
			Std. Error of Mean	7.194E-02	.9313	9.748E-02
			Sum	29.00	454.80	135.00
			Minimum	NO	5.40	2.00
			Maximum	YES	24.80	4.00
			Range	1.00	19.40	2.00
			Std. Deviation	.4606	6.1072	.6392
			Variance	.212	37.298	.409
			Kurtosis	-1.164	.437	-.479
			Std. Error of Kurtosis	.724	.709	.709
			Skewness	-.946	1.355	-.124
			Std. Error of Skewness	.369	.361	.361
	ALARM	1		.	8.00	3.00
		2		.	13.80	2.00
		3		.	5.10	3.00
		4		.	8.60	3.00
		5		.	8.80	2.00
		6		.	6.70	3.00
		Total	N		6	6
			Mean		8.5000	2.6667
			Median		8.3000	3.0000
			Grouped Median		8.3000	2.6667
			Std. Error of Mean		1.2006	.2108
			Sum		51.00	16.00
			Minimum		5.10	2.00
			Maximum		13.80	3.00
			Range		8.70	1.00
			Std. Deviation		2.9407	.5164
			Variance		8.648	.267
			Kurtosis		2.485	-1.875
			Std. Error of Kurtosis		1.741	1.741
			Skewness		1.223	-.968
			Std. Error of Skewness		.845	.845
	Total	N		41	49	49
		Mean		.7073	10.3224	3.0816
		Median		1.0000	8.1000	3.0000
		Grouped Median		.7073	8.1167	3.0976
		Std. Error of Mean		7.194E-02	.8331	9.146E-02
		Sum		29.00	505.80	151.00
		Minimum		NO	5.10	2.00
		Maximum		YES	24.80	4.00
		Range		1.00	19.70	2.00
		Std. Deviation		.4606	5.8318	.6402
		Variance		.212	34.010	.410
		Kurtosis		-1.164	.882	-.458
		Std. Error of Kurtosis		.724	.668	.668
		Skewness		-.946	1.466	-.070
		Std. Error of Skewness		.369	.340	.340

Case Summaries[a]

			TEMP (F)	FOCAL	HARRASSMENT
TEST CONDTION	NO ALARM	1	76.80	13.00	NONE
		2	76.70	3.00	NONE
		3	80.30	13.00	HIGH
		4	81.00	1.00	NONE
		5	81.30	3.00	HIGH
		6	82.10	20.00	NONE
		7	80.50	21.00	HIGH
		8	80.40	4.00	LOW
		9	80.50	18.00	NONE
		10	80.50	9.00	MEDIUM
		11	81.00	18.00	NONE
		12	80.70	11.00	HIGH
		13	80.70	18.00	NONE
		14	81.00	4.00	NONE
		15	81.20	11.00	NONE
		16	81.60	11.00	MEDIUM
		17	81.40	4.00	NONE
		18	81.40	11.00	LOW
		19	80.90	10.00	NONE
		20	80.90	19.00	NONE
		21	81.00	10.00	NONE
		22	75.70	2.00	HIGH
		23	75.80	22.00	LOW
		24	75.80	2.00	NONE
		25	76.30	12.00	LOW
		26	76.00	6.00	NONE
		27	76.30	6.00	NONE
		28	76.20	23.00	NONE
		29	76.40	6.00	LOW
		30	79.30	15.00	LOW
		31	86.10	14.00	NONE
		32	82.20	14.00	NONE
		33	84.70	15.00	NONE
		34	86.40	7.00	LOW
		35	86.70	7.00	NONE
		36	87.30	16.00	MEDIUM
		37	87.40	15.00	NONE
		38	87.50	17.00	NONE
		39	87.60	24.00	MEDIUM
		40	87.60	8.00	LOW
		41	87.70	5.00	LOW
		42	88.00	8.00	LOW
		43	88.70	8.00	LOW

Case Summaries[a]

				TEMP (F)	FOCAL	HARRASSMENT
TEST CONDTION	NO ALARM	Total	N	43	43	43
			Mean	81.5721	11.2558	.7907
			Median	81.0000	11.0000	.0000
			Grouped Median	80.9833	10.8333	.5882
			Std. Error of Mean	.6182	.9622	.1581
			Sum	3507.60	484.00	34.00
			Minimum	75.70	1.00	NONE
			Maximum	88.70	24.00	HIGH
			Range	13.00	23.00	3.00
			Std. Deviation	4.0541	6.3098	1.0364
			Variance	16.436	39.814	1.074
			Kurtosis	-.976	-.907	.027
			Std. Error of Kurtosis	.709	.709	.709
			Skewness	.251	.251	1.115
			Std. Error of Skewness	.361	.361	.361
	ALARM	1		76.30	6.00	MEDIUM
		2		84.60	15.00	MEDIUM
		3		86.80	7.00	MEDIUM
		4		87.20	16.00	HIGH
		5		87.70	17.00	MEDIUM
		6		88.60	25.00	MEDIUM
		Total	N	6	6	6
			Mean	85.2000	14.3333	2.1667
			Median	87.0000	15.5000	2.0000
			Grouped Median	87.0000	15.5000	2.1667
			Std. Error of Mean	1.8614	2.8713	.1667
			Sum	511.20	86.00	13.00
			Minimum	76.30	6.00	MEDIUM
			Maximum	88.60	25.00	HIGH
			Range	12.30	19.00	1.00
			Std. Deviation	4.5594	7.0333	.4082
			Variance	20.788	49.467	.167
			Kurtosis	4.230	-.323	6.000
			Std. Error of Kurtosis	1.741	1.741	1.741
			Skewness	-2.020	.228	2.449
			Std. Error of Skewness	.845	.845	.845
	Total	N		49	49	49
		Mean		82.0163	11.6327	.9592
		Median		81.0000	11.0000	1.0000
		Grouped Median		81.1200	11.2000	.7647
		Std. Error of Mean		.6059	.9151	.1542
		Sum		4018.80	570.00	47.00
		Minimum		75.70	1.00	NONE
		Maximum		88.70	25.00	HIGH
		Range		13.00	24.00	3.00
		Std. Deviation		4.2415	6.4054	1.0793
		Variance		17.991	41.029	1.165
		Kurtosis		-1.224	-.866	-.864
		Std. Error of Kurtosis		.668	.668	.668
		Skewness		.083	.249	.706
		Std. Error of Skewness		.340	.340	.340

a. Limited to first 100 cases.

Frequencies

Statistics

		TRIAL_N	TEST CONDTIO N	DEPTH (FT)	TEMP (F)	SPEED
N	Valid	49	49	49	49	49
	Missing	0	0	0	0	0
Mean		25.0000	1.1224	10.3224	82.0163	3.0816
Std. Error of Mean		2.0412	4.731E-02	.8331	.6059	9.146E-02
Median		25.0000	1.0000	8.1000	81.0000	3.0000
Std. Deviation		14.2887	.3312	5.8318	4.2415	.6402
Variance		204.1667	.1097	34.0097	17.9906	.4099
Skewness		.000	2.377	1.466	.083	-.070
Std. Error of Skewness		.340	.340	.340	.340	.340
Range		48.00	1.00	19.70	13.00	2.00
Minimum		1.00	1.00	5.10	75.70	2.00
Maximum		49.00	2.00	24.80	88.70	4.00
Sum		1225.00	55.00	505.80	4018.80	151.00
Percentiles	25	12.5000	1.0000	6.3000	79.8000	3.0000
	50	25.0000	1.0000	8.1000	81.0000	3.0000
	75	37.5000	1.0000	12.8000	86.7500	3.5000

Statistics

		FOCAL	BEH BEFORE	BEH CNG DURING	BEH CNG VP1	BEH CHG V/P2
N	Valid	49	49	49	41	11
	Missing	0	0	0	8	38
Mean		11.6327	3.3469	4.2653	4.6098	10.1818
Std. Error of Mean		.9151	.6959	.7410	.5306	.8720
Median		11.0000	.0000	.0000	4.0000	11.0000
Std. Deviation		6.4054	4.8715	5.1872	3.3976	2.8920
Variance		41.0289	23.7313	26.9073	11.5439	8.3636
Skewness		.249	.943	.642	.566	-.857
Std. Error of Skewness		.340	.340	.340	.369	.661
Range		24.00	12.00	14.00	12.00	9.00
Minimum		1.00	.00	.00	.00	4.00
Maximum		25.00	12.00	14.00	12.00	13.00
Sum		570.00	164.00	209.00	189.00	112.00
Percentiles	25	6.0000	.0000	.0000	2.0000	8.0000
	50	11.0000	.0000	.0000	4.0000	11.0000
	75	16.5000	7.0000	11.0000	7.0000	13.0000

Statistics

		DISTANCE (m)	HARRASSMENT	CHANGE DURING	CHANGE VEERING /PASSING
N	Valid	49	49	49	41
	Missing	0	0	0	8
Mean		8.1224	.9592	.1837	.7073
Std. Error of Mean		.6861	.1542	5.589E-02	7.194E-02
Median		7.0000	1.0000	.0000	1.0000
Std. Deviation		4.8029	1.0793	.3912	.4606
Variance		23.0680	1.1650	.1531	.2122
Skewness		2.073	.706	1.686	-.946
Std. Error of Skewness		.340	.340	.340	.369
Range		22.00	3.00	1.00	1.00
Minimum		3.00	.00	.00	.00
Maximum		25.00	3.00	1.00	1.00
Sum		398.00	47.00	9.00	29.00
Percentiles	25	6.0000	.0000	.0000	.0000
	50	7.0000	1.0000	.0000	1.0000
	75	8.0000	2.0000	.0000	1.0000

Frequency Table

TRIAL_N

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	1	2.0	2.0	2.0
	2.00	1	2.0	2.0	4.1
	3.00	1	2.0	2.0	6.1
	4.00	1	2.0	2.0	8.2
	5.00	1	2.0	2.0	10.2
	6.00	1	2.0	2.0	12.2
	7.00	1	2.0	2.0	14.3
	8.00	1	2.0	2.0	16.3
	9.00	1	2.0	2.0	18.4
	10.00	1	2.0	2.0	20.4
	11.00	1	2.0	2.0	22.4
	12.00	1	2.0	2.0	24.5
	13.00	1	2.0	2.0	26.5
	14.00	1	2.0	2.0	28.6
	15.00	1	2.0	2.0	30.6
	16.00	1	2.0	2.0	32.7
	17.00	1	2.0	2.0	34.7
	18.00	1	2.0	2.0	36.7
	19.00	1	2.0	2.0	38.8
	20.00	1	2.0	2.0	40.8
	21.00	1	2.0	2.0	42.9
	22.00	1	2.0	2.0	44.9
	23.00	1	2.0	2.0	46.9
	24.00	1	2.0	2.0	49.0
	25.00	1	2.0	2.0	51.0
	26.00	1	2.0	2.0	53.1
	27.00	1	2.0	2.0	55.1
	28.00	1	2.0	2.0	57.1
	29.00	1	2.0	2.0	59.2
	30.00	1	2.0	2.0	61.2
	31.00	1	2.0	2.0	63.3
	32.00	1	2.0	2.0	65.3
	33.00	1	2.0	2.0	67.3
	34.00	1	2.0	2.0	69.4
	35.00	1	2.0	2.0	71.4
	36.00	1	2.0	2.0	73.5
	37.00	1	2.0	2.0	75.5
	38.00	1	2.0	2.0	77.6
	39.00	1	2.0	2.0	79.6
	40.00	1	2.0	2.0	81.6
	41.00	1	2.0	2.0	83.7
	42.00	1	2.0	2.0	85.7
	43.00	1	2.0	2.0	87.8
	44.00	1	2.0	2.0	89.8
	45.00	1	2.0	2.0	91.8
	46.00	1	2.0	2.0	93.9
	47.00	1	2.0	2.0	95.9
	48.00	1	2.0	2.0	98.0
	49.00	1	2.0	2.0	100.0
	Total	49	100.0	100.0	

TEST CONDTION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO ALARM	43	87.8	87.8	87.8
	ALARM	6	12.2	12.2	100.0
	Total	49	100.0	100.0	

DEPTH (FT)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5.10	1	2.0	2.0	2.0
	5.40	2	4.1	4.1	6.1
	5.50	2	4.1	4.1	10.2
	5.70	2	4.1	4.1	14.3
	5.80	1	2.0	2.0	16.3
	6.00	2	4.1	4.1	20.4
	6.20	1	2.0	2.0	22.4
	6.30	3	6.1	6.1	28.6
	6.40	1	2.0	2.0	30.6
	6.70	1	2.0	2.0	32.7
	6.90	1	2.0	2.0	34.7
	8.00	6	12.2	12.2	46.9
	8.10	2	4.1	4.1	51.0
	8.20	4	8.2	8.2	59.2
	8.40	1	2.0	2.0	61.2
	8.60	1	2.0	2.0	63.3
	8.80	3	6.1	6.1	69.4
	9.10	1	2.0	2.0	71.4
	9.20	1	2.0	2.0	73.5
	12.20	1	2.0	2.0	75.5
	13.40	1	2.0	2.0	77.6
	13.70	1	2.0	2.0	79.6
	13.80	1	2.0	2.0	81.6
	16.60	1	2.0	2.0	83.7
	16.80	1	2.0	2.0	85.7
	19.40	1	2.0	2.0	87.8
	20.40	1	2.0	2.0	89.8
	23.60	1	2.0	2.0	91.8
	23.70	2	4.1	4.1	95.9
	23.80	1	2.0	2.0	98.0
	24.80	1	2.0	2.0	100.0
	Total	49	100.0	100.0	

TEMP (F)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	75.70	1	2.0	2.0	2.0
	75.80	2	4.1	4.1	6.1
	76.00	1	2.0	2.0	8.2
	76.20	1	2.0	2.0	10.2
	76.30	3	6.1	6.1	16.3
	76.40	1	2.0	2.0	18.4
	76.70	1	2.0	2.0	20.4
	76.80	1	2.0	2.0	22.4
	79.30	1	2.0	2.0	24.5
	80.30	1	2.0	2.0	26.5
	80.40	1	2.0	2.0	28.6
	80.50	3	6.1	6.1	34.7
	80.70	2	4.1	4.1	38.8
	80.90	2	4.1	4.1	42.9
	81.00	4	8.2	8.2	51.0
	81.20	1	2.0	2.0	53.1
	81.30	1	2.0	2.0	55.1
	81.40	2	4.1	4.1	59.2
	81.60	1	2.0	2.0	61.2
	82.10	1	2.0	2.0	63.3
	82.20	1	2.0	2.0	65.3
	84.60	1	2.0	2.0	67.3
	84.70	1	2.0	2.0	69.4
	86.10	1	2.0	2.0	71.4
	86.40	1	2.0	2.0	73.5
	86.70	1	2.0	2.0	75.5
	86.80	1	2.0	2.0	77.6
	87.20	1	2.0	2.0	79.6
	87.30	1	2.0	2.0	81.6
	87.40	1	2.0	2.0	83.7
	87.50	1	2.0	2.0	85.7
	87.60	2	4.1	4.1	89.8
	87.70	2	4.1	4.1	93.9
	88.00	1	2.0	2.0	95.9
	88.60	1	2.0	2.0	98.0
	88.70	1	2.0	2.0	100.0
	Total	49	100.0	100.0	

SPEED

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.00	8	16.3	16.3	16.3
	3.00	29	59.2	59.2	75.5
	4.00	12	24.5	24.5	100.0
	Total	49	100.0	100.0	

FOCAL

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	1	2.0	2.0	2.0
	2.00	2	4.1	4.1	6.1
	3.00	2	4.1	4.1	10.2
	4.00	3	6.1	6.1	16.3
	5.00	1	2.0	2.0	18.4
	6.00	4	8.2	8.2	26.5
	7.00	3	6.1	6.1	32.7
	8.00	3	6.1	6.1	38.8
	9.00	1	2.0	2.0	40.8
	10.00	2	4.1	4.1	44.9
	11.00	4	8.2	8.2	53.1
	12.00	1	2.0	2.0	55.1
	13.00	2	4.1	4.1	59.2
	14.00	2	4.1	4.1	63.3
	15.00	4	8.2	8.2	71.4
	16.00	2	4.1	4.1	75.5
	17.00	2	4.1	4.1	79.6
	18.00	3	6.1	6.1	85.7
	19.00	1	2.0	2.0	87.8
	20.00	1	2.0	2.0	89.8
	21.00	1	2.0	2.0	91.8
	22.00	1	2.0	2.0	93.9
	23.00	1	2.0	2.0	95.9
	24.00	1	2.0	2.0	98.0
	25.00	1	2.0	2.0	100.0
	Total	49	100.0	100.0	

BEH BEFORE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	R	32	65.3	65.3	65.3
	F	8	16.3	16.3	81.6
	SS	9	18.4	18.4	100.0
	Total	49	100.0	100.0	

BEH CNG DURING

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	R	25	51.0	51.0	51.0
	SD	1	2.0	2.0	53.1
	FS-A	2	4.1	4.1	57.1
	S-CH	1	2.0	2.0	59.2
	O-B	1	2.0	2.0	61.2
	F	6	12.2	12.2	73.5
	S-A	3	6.1	6.1	79.6
	SS	9	18.4	18.4	98.0
	D	1	2.0	2.0	100.0
	Total	49	100.0	100.0	

BEH CNG VP1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	R	6	12.2	14.6	14.6
	SD	2	4.1	4.9	19.5
	FS-A	4	8.2	9.8	29.3
	O-B	15	30.6	36.6	65.9
	FS	1	2.0	2.4	68.3
	D-CH	1	2.0	2.4	70.7
	F	4	8.2	9.8	80.5
	SS-B	2	4.1	4.9	85.4
	SS-A	1	2.0	2.4	87.8
	0-A	2	4.1	4.9	92.7
	S-A	1	2.0	2.4	95.1
	SS	2	4.1	4.9	100.0
	Total	41	83.7	100.0	
Missing	System	8	16.3		
Total		49	100.0		

BEH CHG V/P2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-B	1	2.0	9.1	9.1
	SS-B	2	4.1	18.2	27.3
	SS-A	2	4.1	18.2	45.5
	S-A	2	4.1	18.2	63.6
	S-B	4	8.2	36.4	100.0
	Total	11	22.4	100.0	
Missing	System	38	77.6		
Total		49	100.0		

DISTANCE (m)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3.00	1	2.0	2.0	2.0
	4.00	6	12.2	12.2	14.3
	5.00	4	8.2	8.2	22.4
	6.00	11	22.4	22.4	44.9
	7.00	12	24.5	24.5	69.4
	8.00	5	10.2	10.2	79.6
	10.00	2	4.1	4.1	83.7
	13.00	2	4.1	4.1	87.8
	15.00	2	4.1	4.1	91.8
	17.00	1	2.0	2.0	93.9
	20.00	1	2.0	2.0	95.9
	23.00	1	2.0	2.0	98.0
	25.00	1	2.0	2.0	100.0
	Total	49	100.0	100.0	

HARRASSMENT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NONE	23	46.9	46.9	46.9
	LOW	11	22.4	22.4	69.4
	MEDIUM	9	18.4	18.4	87.8
	HIGH	6	12.2	12.2	100.0
	Total	49	100.0	100.0	

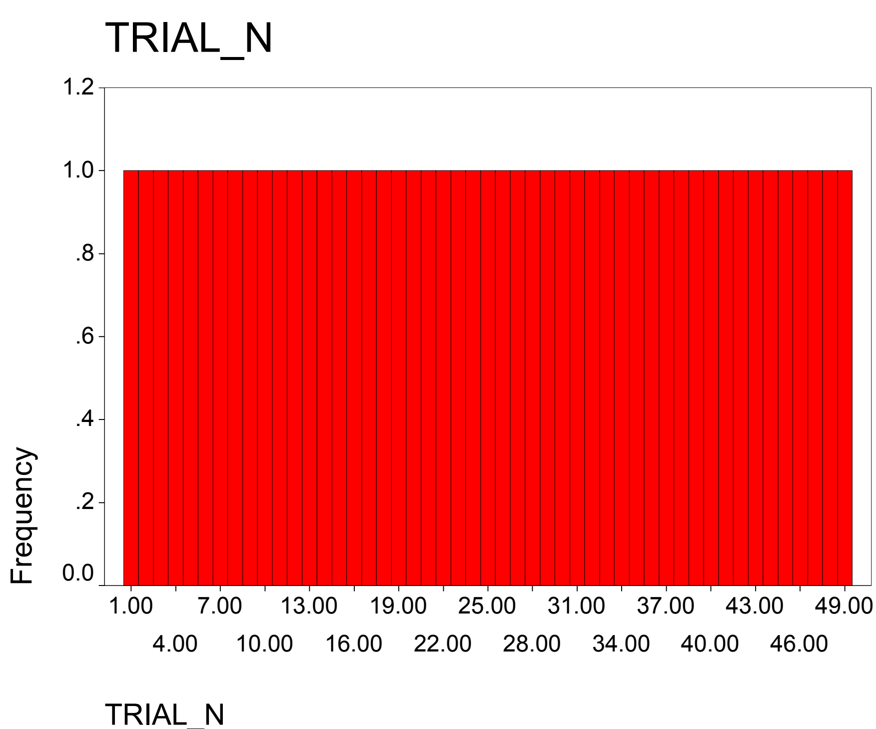
CHANGE DURING

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	40	81.6	81.6	81.6
	YES	9	18.4	18.4	100.0
	Total	49	100.0	100.0	

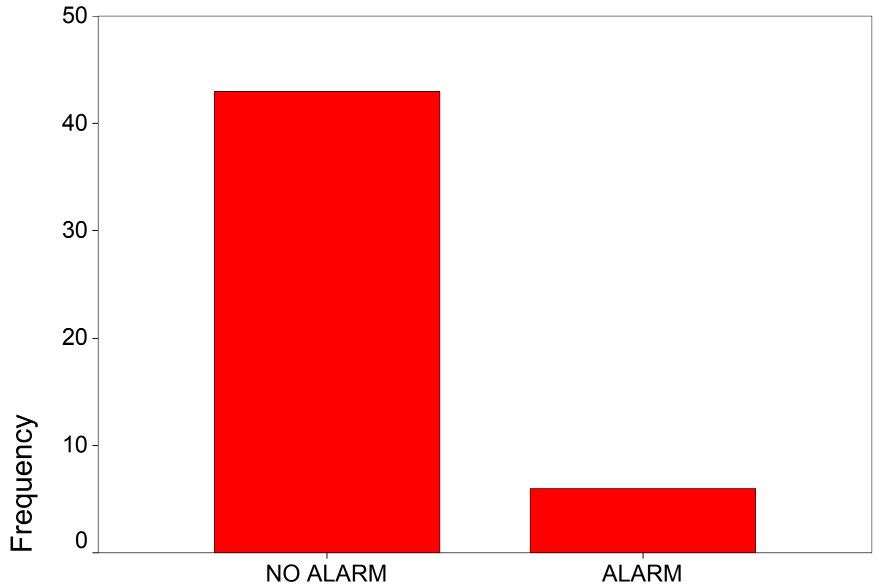
CHANGE VEERING /PASSING

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	12	24.5	29.3	29.3
	YES	29	59.2	70.7	100.0
	Total	41	83.7	100.0	
Missing	System	8	16.3		
Total		49	100.0		

Bar Chart

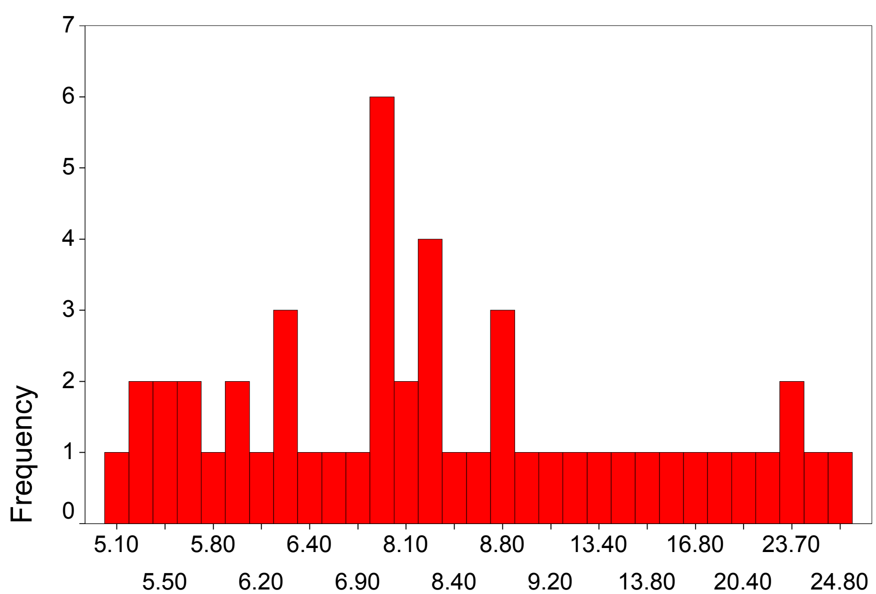


TEST CONDTION



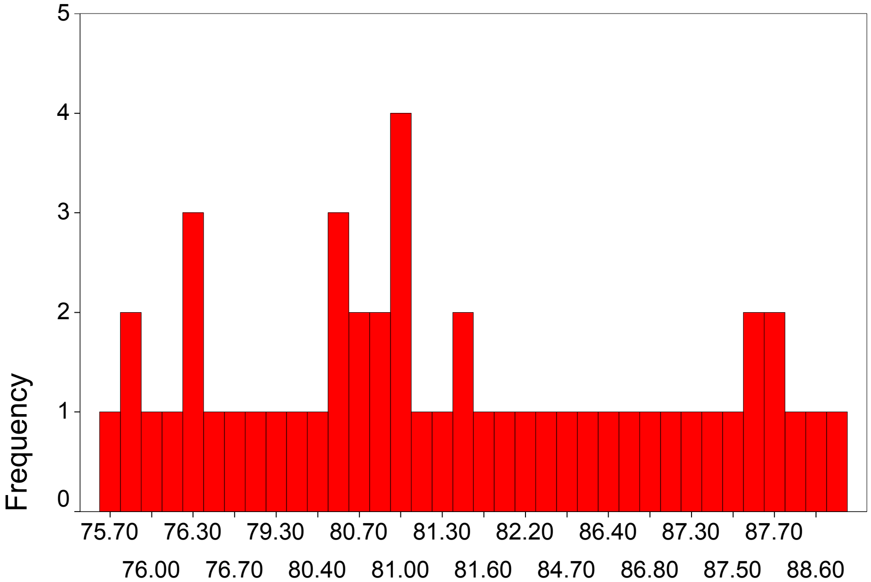
TEST CONDTION

DEPTH (FT)



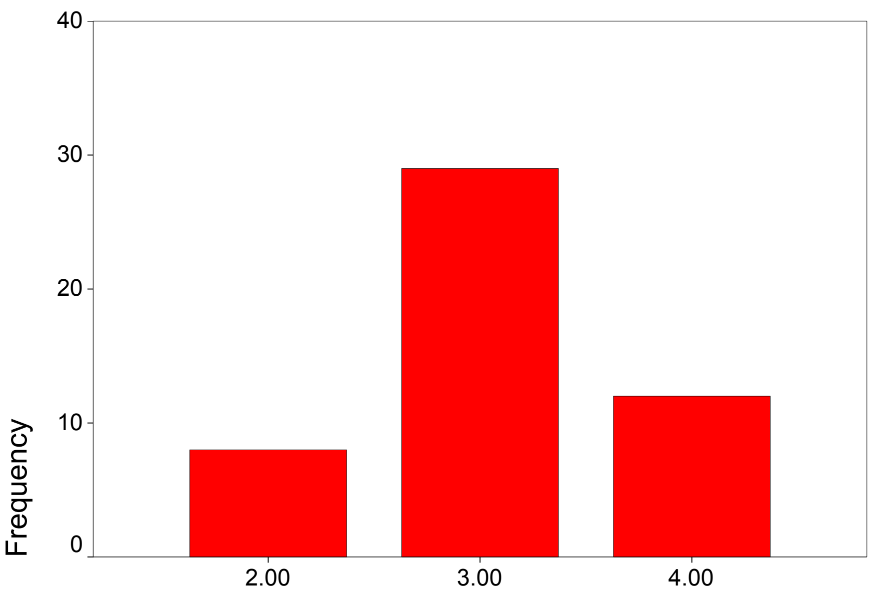
DEPTH (FT)

TEMP (F)

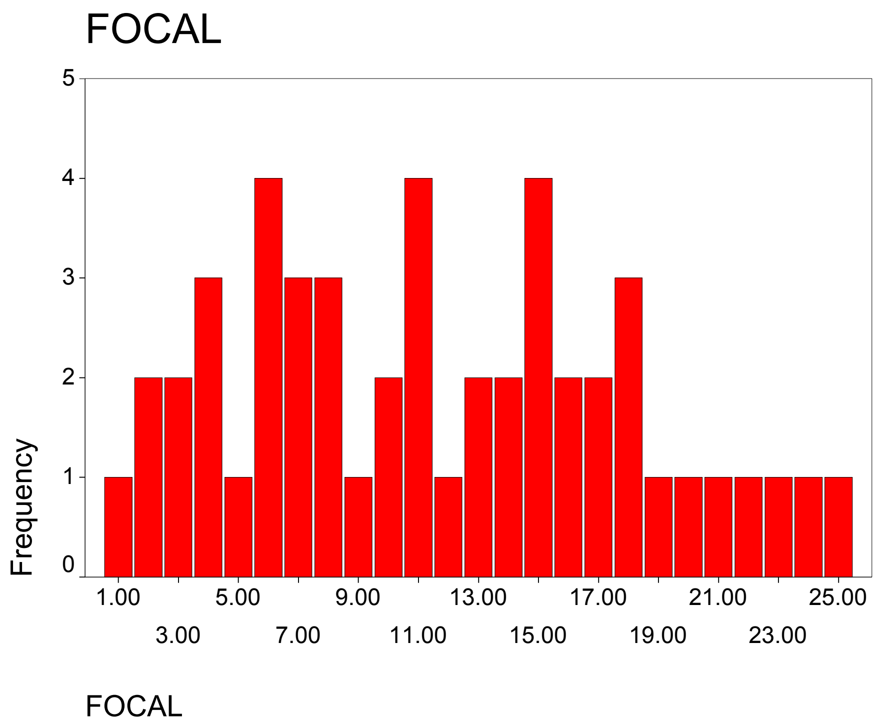


TEMP (F)

SPEED



SPEED


FOCAL
5
4
3
2
1
0
Frequency
1.00
3.00
5.00
7.00
9.00
11.00
13.00
15.00
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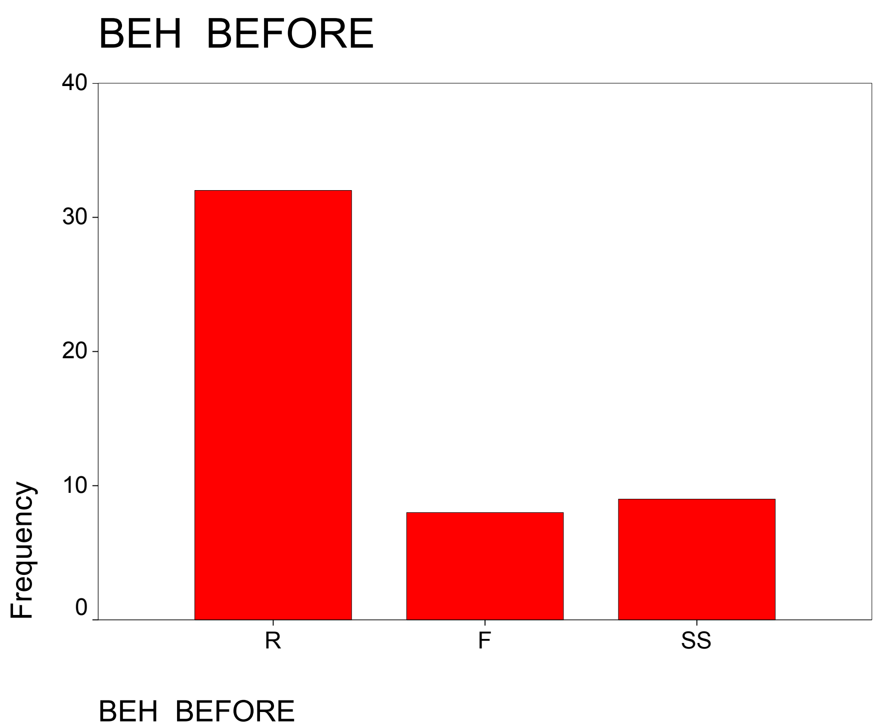
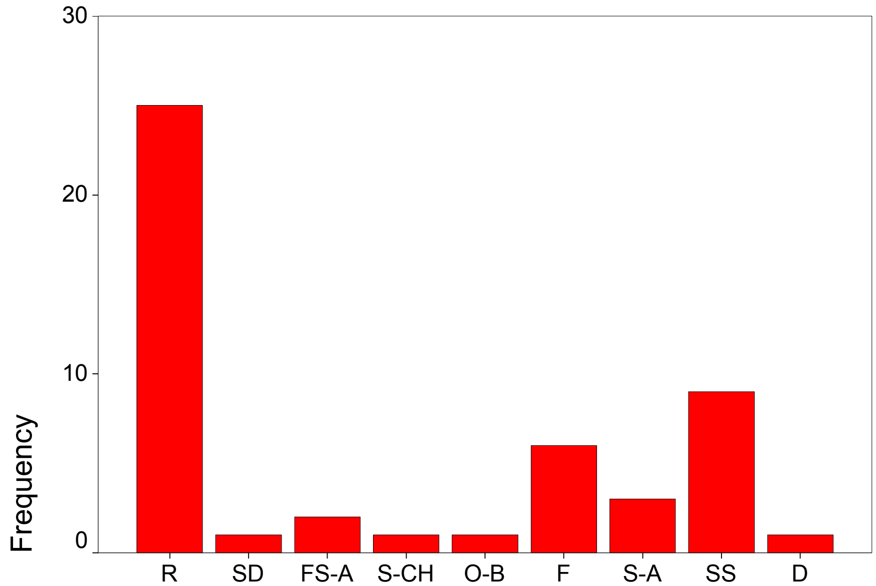
21.00
23.00
25.00
FOCAL

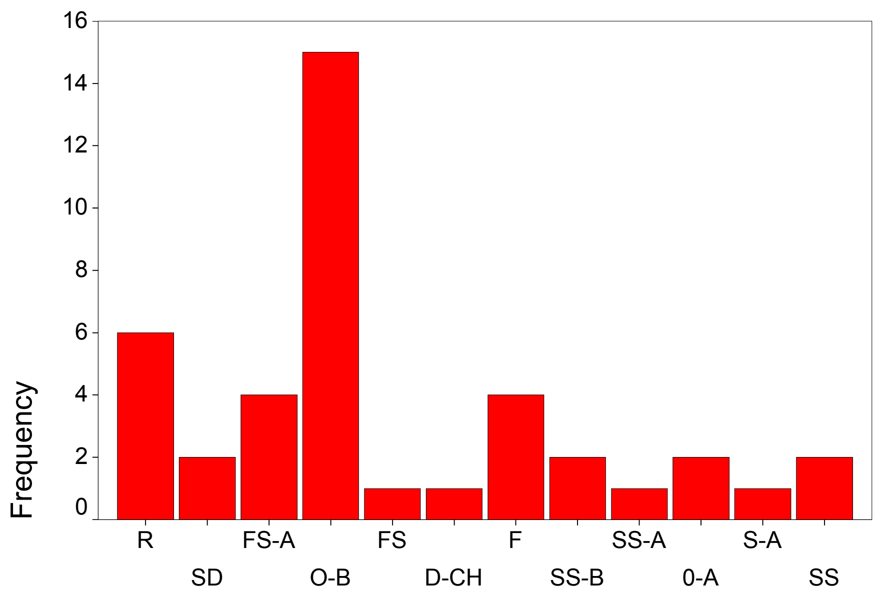

BEH BEFORE
40
30
20
10
0
Frequency
R
F
SS
BEH BEFORE

BEH CNG DURING



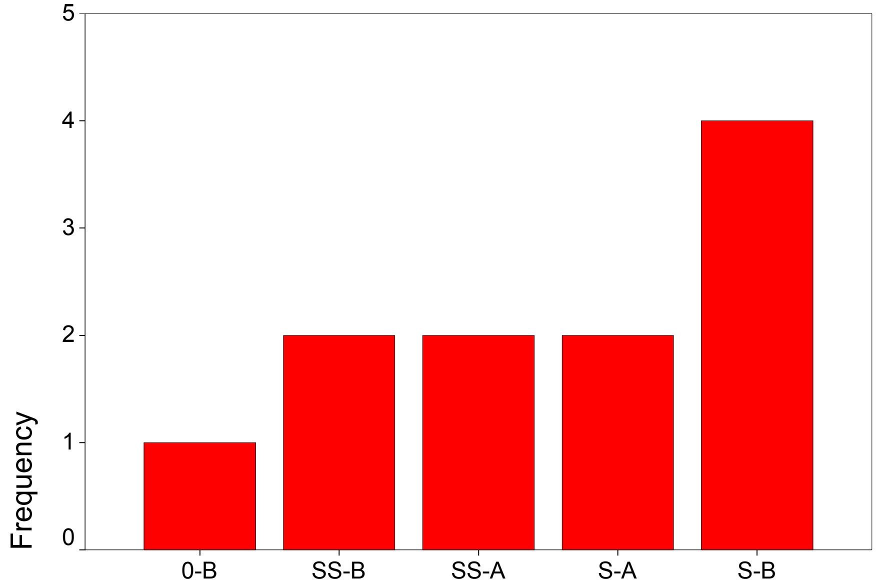
BEH CNG DURING

BEH CNG VP1



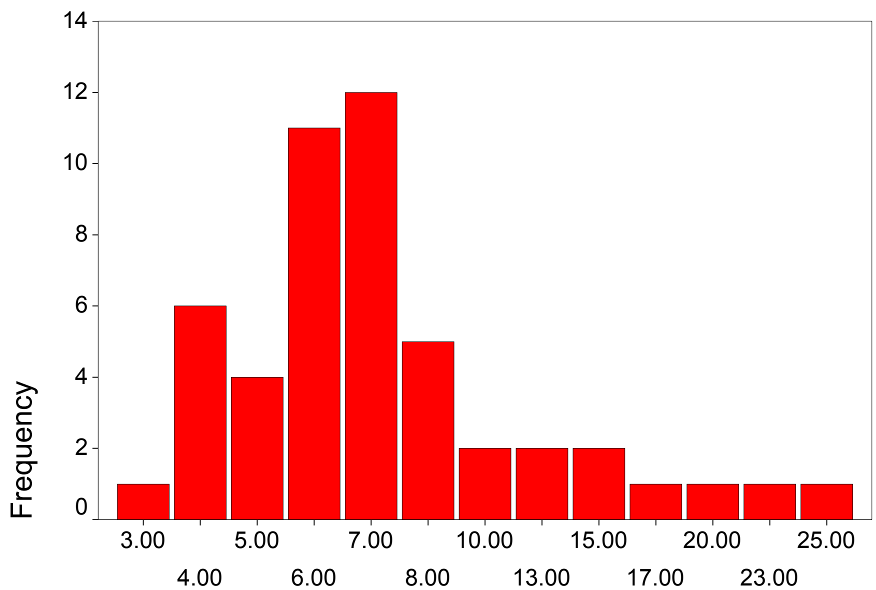
BEH CNG VP1

BEH CHG V/P2



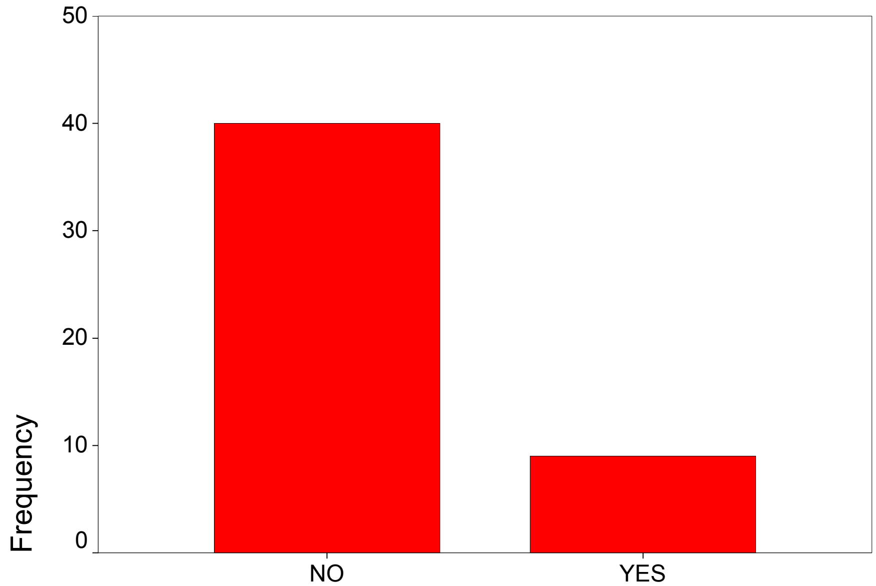
BEH CHG V/P2

DISTANCE (m)



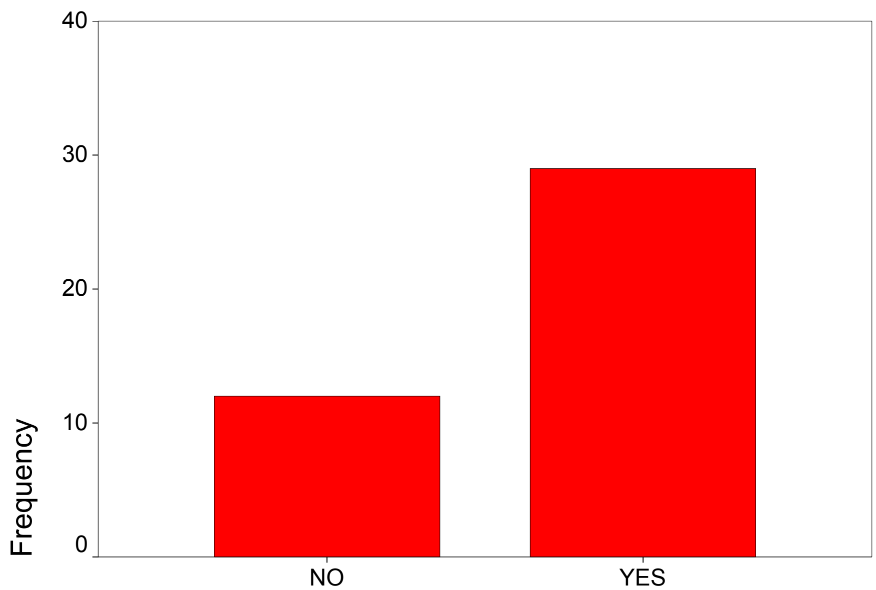
DISTANCE (m)

CHANGE DURING



CHANGE DURING

CHANGE VEERING /PASSING



CHANGE VEERING /PASSING

TABLE I

DATE	TAPE	TIME	TIME CODE	TRIAL	TYPE	GPS	BUOY	WATER DEPTH	WATER TEMP	BOAT SPEED	N	FOCAL ID	BEHAVIOR BEFORE-APP	BEHAVIOR DURING-APP	BEHAVIOR VEERING/PASS	MIN DIST (M)	HARRASSED N/Y (L,M,H)
5/3/2007	2/P2	11:18:37 AM	00 23 28.18	1	S	N28 30.608 W80 35.679	2	5.5 ft	76.8 °F	2 mph	1	SPLOTCH	R	R	O-B	4	N
5/3/2007	2/P2	10:21:31 AM	00 25 31 02	2	S	N28 30.608 W80 35.679	2	5.5 ft	76.7 °F	2 mph	1	COSMOS	SS	SS	SS-B	5	N
5/3/2007	2.5/P2	12:44:29 PM	00 13 46.22	3	S	N28 30.608 W80 35.667	6	5.4 ft	80.3 °F	3 mph	1	SPLOTCH	R	R	FS-A	6	YH
5/4/2007	2.5/P2	10:53:50 AM	00 01 51.08	4	S	N28 30.894 W80 35.918	3	5.8 ft	81.0 °F	4 mph	1	BIG MAMA	SS	SS	O-B	8	N
5/4/2007	2.5/P2	11:09:04 AM	00 04 38.05	5	S	N28 30.911 W80 35.865	1	6.3 ft	81.3 °F	4 mph	1	COSMOS	SS	SS	FS-A	6	YH
5/4/2007	2.5/P2	11:50:53 AM	00 10 05.20	6	S	N28 30.911 W80 35.837	1	6.3 ft	82.1 °F	3 mph	1	UK	F	0-B	SS-B	10	YL
5/5/2007	3/P2	10:49:46 AM	00 05 31.24	7	S	N28 30.375 W80 35.369	5	23.7 ft	80.5 °F	3 mph	1	UK	R	SD		13	YH
5/5/2007	3/P2	11:01:13 AM	00 07 11.05	8	S	N28 30.320 W80 35.517	6	23.7 ft	80.4 °F	4 mph	1	GRAY	R	R	SD	6	YL
5/5/2007	3/P2	11:26:37 AM	00 08 16.25	9	S	N28 30.336 W80 35.468	3	8.2 ft	80.5 °F	3 mph	1	TIGER TAIL	SS	SS	SS	6	N
5/5/2007	3/P2	11:35:02 AM	00 09 45 09	10	S	N28 30.355 W80 35.320	7	6.9 ft	80.5 °F	3 mph	1	KOKO	R	R	S-A	4	YM
5/5/2007	3/P2	11:40:07 AM	00 11 23.19	11	S	N28 30.330 W80 35.468	3	8.2 ft	81.0 °F	4 mph	1	TIGER TAIL	R	R	SS	8	N
5/5/2007	3/P2	12:00:08 PM	00 15 12.13	12	S	N28 30.312 W80 35.472	1	5.7 ft	80.7 °F	3 mph	1	ONYX	SS	SS	FS-A	7	YH
5/5/2007	3/P2	12:10:24 PM	00 17 14.21	13	S	N28 30.322 W80 35.479	8	13.4 ft	80.7 °F	3 mph	1	TIGER TAIL	R	R	R	7	N
5/5/2007	3/P2	12:36:16 PM	00 19 36.29	14	S	N28 30.316 W80 35.508	4	23.8 ft	81.0 °F	3 mph	1	GRAY	R	R	0-B	7	N
5/5/2007	3/P2	12:43:12 PM	00 21 15.01	15	S	N28 30.345 W80 35.366	2	5.4 ft	81.2 °F	3 mph	1	ONYX	R	R	R	6	N
5/5/2007	3/P2	12:22:22 PM	00 23 29.10	16	S	N28 30.324 W80 35.472	1	5.7 ft	81.6 °F	4 mph	1	ONYX	R	S-CH		13	YM
5/5/2007	3/P2	1:05:00 PM	00 24 36.18	17	S	N28 30.336 W80 35.468	3	8.2 ft	81.4 °F	3 mph	1	GRAY	R	R	0-B	6	N
5/5/2007	3/P2	1:35:10 PM	00 25 50.28	18	S	N28 30.330 W80 35.468	3	8.2 ft	81.4 °F	3 mph	1	ONYX	R	R	SS-A	6	YL
5/6/2007	4/P2	10:21:46 AM	00 00 05.28	19	S	N28 30.340 W80 35.364	1	19.4 ft	80.9 °F	3 mph	1	MOHAWK	R	R	R	9	N
5/6/2007	4/P2	10:26:52 AM	00 01 39.20	20	S	N28 30.384 W80 35.407	8	24.8 ft	80.9 °F	3 mph	1	TRIDOT	SS	SS	SD	7	N
5/6/2007	4/P2	10:35:34 AM	00 03 16.14	21	S	N28 30.358 W80 35.402	4	20.4 ft	81.0 °F	4 mph	1	MOHAWK	R	R	R	7	N
5/16/2007	5/P2	10:45:21 AM	00 00 00.14	22	S	N28 30.344 W80 35.435	5	23.6 ft	75.7 °F	3 mph	1	BILL	R	R	FS-A	7	YH
5/16/2007	5/P2	10:48:21 AM	00 01 33.26	23	S	N28 30.331 W80 35.429	8	16.8 ft	75.8 °F	3 mph	1	UK	SS	SS	O-B, SS-B	7	YL
5/16/2007	5/P2	10:52:45 AM	00 02 43.00	24	S	N28 30.331 W80 35.429	8	16.6 ft	75.8 °F	4 mph	1	BILL	SS	SS	O-B	5	N
5/28/2007	7/P2	10:45:37 AM	00 05 58.06	25	S	N28 30.326 W80 35.424	8	8.0 ft	76.3 °F	4 mph	1	PATCHES	R	R	O-B, SS-A	6	YL
5/28/2007	7/P2	11:00:38 AM	00 07 03.27	26	S	N28 30.329 W80 35.437	7	9.1 ft	76.0 °F	4 mph	1	HIPP	F	F	F	8	N
5/28/2007	7/P2	11:38:05 AM	00 08 10.11	27	S	N28 30.326 W80 35.424	8	8.0 ft	76.3 °F	4 mph	1	HIPP	R	R	O-B	3	N
5/28/2007	7/P2	12:12:50 AM	00 14 55.01	28	S	N28 30.329 W80 35.439	6,7	12.2 ft	76.2 °F	3 mph	1	UK	F	F	F	8	N
5/28/2007	7/P2	12:47:02 AM	00 16 35.23	29	A	N28 30.326 W80 35.424	8	8.0 ft	76.3 °F	3 mph	1	HIPP	R	S-A		23	YM
5/28/2007	7/P2	10:37:33 AM	00 17 14.12	30	S	N28 30.322 W80 35.437	7	9.2 ft	76.4 °F	3 mph	1	HIPP	R	R	O-B, SS-A	7	YL
6/6/2007	7/P2	11:06:33 AM	00 01 46.13	31	S	N28 30.309 W80 35.459	8	6.3 ft	79.3 °F	2 mph	1	TAIL SCAR	R	R	O-B, S-B	4	YL
7/6/2007	8/P2	2:06:02 PM	00 01 08 08	32	S	N28 30.775 W80 35.429	5,8	8.8 ft	86.1 °F	3 mph	1	TAIL DOT	F	F	F	6	N
7/6/2007	8/P2	2:41:39 PM	00 06 45 07	33	S	N28 30.775 W80 35.420	4,5	8.8 ft	82.2 °F	3 mph	1	TAIL DOT	R	R	O-B,SS-A	5	N
7/7/2007	8/P2	12:58:41 PM	00 13 58 10	34	S	N28 30.802 W80 36.630	6	6.4 ft	84.7 °F	3 mph	1	TAIL SCAR	R	R	R	7	N
7/7/2007	8/P2	1:38:14 PM	00 15 56 00	35	A	N28 30.797 W80 36.660	2	13.8 ft	84.6 °F	2 mph	1	TAIL SCAR	R	S-A		15	YM
7/9/2007	9/P2	2:07:32 PM	00 06 11 03	36	S	N28 30.780 W80 36.643	1	13.7 ft	86.4 °F	2 mph	1	INK SPOT	SS	SS	FS, O-B	7	YL
7/9/2007	9/P2	2:44:35 PM	00 07 58 20	37	S	N28 30.781 W80 36.637	3	6.0 ft	86.7 °F	4 mph	1	INK SPOT	F	F	F	7	N
7/9/2007	9/P2	3:27:36 PM	00 12 43 13	38	A	N28 30.773 W80 36.640	5	5.1 ft	86.8 °F	3 mph	1	INK SPOT	R	S-A		17	YM
7/17/2007	10/P2	11:16:54 AM	00 05 28.10	39	S	N28 30.775 W80 36.647	1	8.1 ft	87.3 °F	2 mph	1	TEARDROP	R	R	O-A,S-A	7	YM
7/17/2007	10/P2	12:23:58 PM	00 06 59.12	40	S	N28 30.772 W80 36.642	7	8.1 ft	87.4 °F	2 mph	1	TAIL SCAR	R	R	O-B	4	N
7/17/2007	10/P2	12:27:08 PM	00 08 24.10	41	A	N28 30.779 W80 36.645	3	8.6 ft	87.2 °F	3 mph	1	TEARDROP	R	FS-A		20	YH
7/17/2007	10/P2	12:36:34 PM	00 09 28.24	42	S	N28 30.779 W80 36.645	3	8.4 ft	87.5 °F	3 mph	1	THREE	R	R	R	4	N
7/17/2007	10/P2	12:42:24 PM	00 10 22.20	43	S	N28 30.775 W80 36.647	1	8.0 ft	87.6 °F	3 mph	1	UK	F	F	O-A, S-A	5	YM
7/17/2007	10/P2	12:53:19 PM	00 12 16.06	44	S	N28 30.775 W80 36.647	1	8.0 ft	87.6 °F	3 mph	1	JUEY	R	R	O-B, S-B	6	YL
7/17/2007	10/P2	12:57:24 PM	00 13 17.20	45	S	N28 30.775 W80 36.647	1	8.0 ft	87.7 °F	4 mph	1	HILO	F	F	O-B	10	YL
7/17/2007	10/P2	1:31:55 PM	00 12 16.06	46	S	N28 30.780 W80 36.641	4	6.2 ft	88.0 °F	3 mph	1	JUEY	R	R	O-B, S-B	6	YL
7/17/2007	10/P2	1:38:06 PM	00 18 37.00	47	A	N28 30.779 W80 36.645	3	8.8 ft	87.7 °F	2 mph	1	THREE	F	FS-A		15	YM
7/17/2007	10/P2	2:31:52 PM	00 24 45.20	48	S	N28 30.786 W80 36.650	5	6.0 ft	88.7 °F	3 mph	1	JUEY	R	R	O-B,S-B	4	YL
7/17/2007	10/3CP	2:37:10 PM	00 27 23.25	49	A	N28 30.773 W80 36.638	2	6.7 ft	88.6 °F	3 mph	1	UK	R	D		25	YM
5/5/2007	3/P2	12:12:33 PM	00 17 59.12	AB	S	N28 30.320 W80 35.517	6	23.9 ft	80.7 °F	3 mph	1	UK	SS	SS		20	YM
5/16/2007	5/P2	11:55:54 AM	00 04 01.08	AB	S	N28 30.330 W80 35.437	6	17.2 ft	75.7 °F	3 mph	1	BILL	SS	SS		28	N
7/9/2007	9/P2	3:21:17 PM	00 10 06 20	AB	S	N28 30.798 W80 36.659		12.7 ft	86.9 °F	3 mph	1	INK SPOT	F	F		35	N
5/5/2007	3/P2	10:33:53 AM	00 02 27.12	AB	S	N28 30.345 W80 35.366	2	5.4 ft	80.2 °F	3 mph	1	LIGHT MAMA	F	F		40	N
5/5/2007	3/P2	12:50:32 PM	00 22 36.01	AB	S	N28 30.320 W80 35.517	6	24.0 ft	81.1 °F	3 mph	1	UK	SS	SS		40	N
7/17/2007	10/P2	1:28:14 PM	00 14 55.15	AB	S	N28 30.780 W80 36.641		6.2 ft	88.0 °F	3 mph	1	JUEY	R	R		40	N
5/6/2007	4/P2	10:59:28 AM	00 05 14.18	AB	S	N28 30.360 W80 35.406		29.6 ft	81.4 °F	4 mph	1	UK	SS	SS		46	N
5/6/2007	4/P2	10:34:10 AM	00 02 55.02	AB	S	N28 30.338 W80 35.378		19.0 ft	81.0 °F	3 mph	1	UK	SS	SS		50	N

Type Key: S= No Alarm; A= Alarm

Behavior Key: D= Dive; D-CH= Dive toward Channel; F= Feeding; FD-B= Fast Dive toward Boat; FS= Fast Swim; FS-A= Fast Swim Away; FS-B= Fast Swim toward Boat; O-A= Change in Orientation away Boat ; O-B= Change in Orientation toward Boat; R= Resting; S-A= Swim Away; S-CH= Swim toward Channel; SD= Slow Dive; SS= Slow Swim; SS-A= Slow Swim Away; SS-B Slow Swim toward Boat

Harassment Key: N= No; Y= Yes; L= Low; M= Medium; H= High