RV Neil Armstrong

Cruise #25 Report
ADEON Deployment

19 Nov – 15 Dec 2017
Woods Hole, MA to Woods Hole, MA

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Cruise Summary

The objectives for this cruise were to deploy bottom landers at seven sites along the shelfbreak (depths ranging from 200 – 900 m roughly), collect CTD profiles to characterize hydrographic conditions at the sites, conduct net sampling to collect biological specimens at each site, conduct fine-scale (roughly 10 km by 10 km) multi-frequency acoustic surveys at each site, conduct transmission loss experiments at a sub-set of the seven sites, and at the Virginia Inter-Canyon site to recover, download data, and redeploy the bottom lander (Figure 1). All cruise objectives were completed safely. We were fortunate to have good weather for the first half of the cruise which allowed us to complete additional net tows, CTD, and fine-scale acoustic surveys at some sites (Table 1). This also provided a buffer time-wise during the second half as weather conditions were poorer and resulted in several 12-24 hour periods where we were unable to conduct any sampling. We appreciate the excellent work of the ship's Captain and crew (in all aspects on the boat) in helping us to accomplish our cruise objectives. Cruise AR25 was Cruise 1 for the ADEON project.

Table 1. Summary of sampling that occurred at each site location during the AR 25 research cruise. We were able to accomplish additional sampling at the VAC, HAT, and WIL sites (indicated by a + sign). The * indicates that the lander was recovered and redeployed on the return leg of the cruise allowing us to return to the dock with ~ 2 weeks of data from the initial deployment.

Site	**Lander Deployed**	**CTD casts**	**Ring net tows**	**IKMT net tows**	**Finescale Acoustic Survey**	**Transmission Loss Experiment**	**eDNA samples collected**	**Fish specimens preserved**
VAC	Yes*	12+3	2	6	Yes (2)	Yes	Yes	Yes
HAT	Yes	6+1	1	4	Yes		Yes	Yes
WIL	Yes	6+1	1	3	Yes	Yes	Yes	Yes
SAV	Yes	4	1	3	Yes	Yes		Yes
BLE	Yes	4	1	3	Yes			Yes
JAX	Yes	6	1	2	Yes	Yes		Yes
CHB	Yes	5	1	2	Yes			Yes
Cruise Total	7*	48	8	23	8	4	3	

Figure 1. Cruise track for RV Armstrong Cruise #25 from Nov 19 through 15 December showing the location of all seven sites.

Bottom Lander Deployment – Carmen Lawrence

Each ADEON lander consisted of a frame containing all monitoring equipment, a 350 kg anchor frame tensioned to the lander frame via two acoustic releases, and a lift point for deployment and retrieval purposes. Each lander had three glass spheres to provide buoyancy.

ADEON landers were deployed at each of the seven study sites (Table 2) using the ship's A-frame and a quick release mechanism. Each lander contained a passive acoustic monitoring system with hydrophones in an orthogonal array setup (except for the lander deployed at VA2, which had an omnidirectional sensor and a single hydrophone) (Figure 2). Each lander also contained a conductivity, temperature, and optical dissolved oxygen sensor. Accessories consisted of an iridium tracking beacon and a flasher beacon intended to assist with recovery. Three stations (VAC, HAT & JAX) had an AZFP active acoustic system and VEMCO fish tag receiver.

Table 2. Deployment location (where the ship was when the lander was released at the surface) and estimated final lander location on bottom (determined by acoustic triangulation post-deployment) of the eight lander deployments. VAC and VA2 are the first and second deployment of the lander at the Virginia Inter-canyon site.

Site	Deployment Location		Estimated Location		Depth (m)
	Latitude	Longitude	Latitude	Longitude	
VAC	37 14.7708 N	074 30.8352 W	37 14.7902 N	074 30.8161 W	213
HAT	35 11.9730 N	075 01.2228 W	35 11.9808 N	075 01.1895 W	296
WIL	33 35.1144 N	076 27.0336 W	33 35.1144 N	076 27.0336 W	461
SAV	32 02.5308 N	077 20.8740 W	32 02.6227 N	077 20.7940 W	790
BLE	29 15.0588 N	078 21.0450 W	29 15.0524 N	078 21.1079 W	872
JAX	30 29.5644 N	080 00.1872 W	30 29.6398 N	080 00.1398 W	317
CHB	32 04.2150 N	078 22.4430 W	32 04.2311 N	078 22.3847 W	404
VA2	37 14.7792 N	074 30.8124 W	37 14.7724 N	074 30.7895 W	212

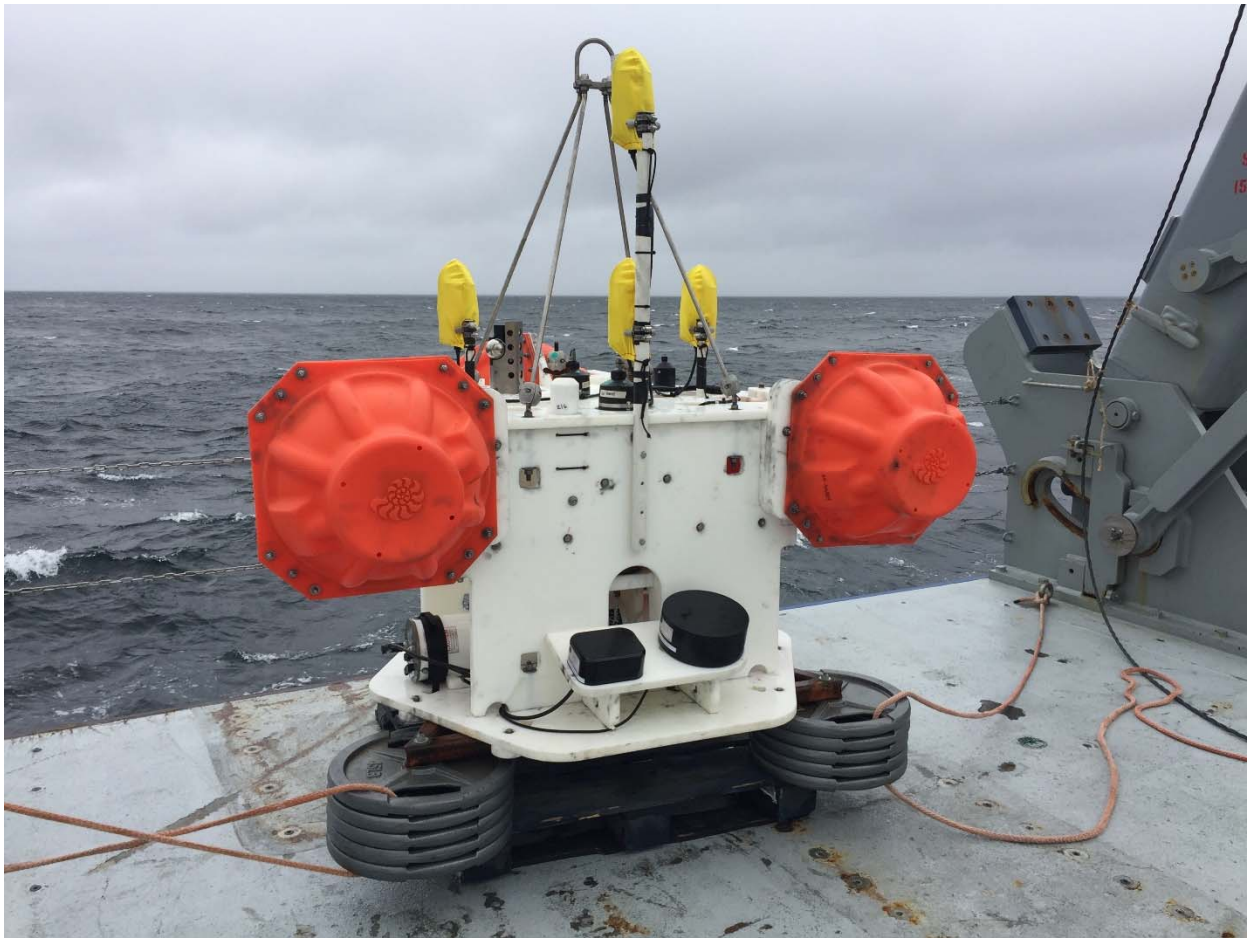
Figure 2. ADEON lander on the fantail ready for deployment.

Prior to deployment, the bathymetry at each study site was mapped with multibeam to determine an appropriate drop location for the lander. Any uneven bathymetric zones were avoided. The landers sink at approximately 1.5 m/s, so current was also taken into consideration when a drop location was chosen.

After each lander was deployed, the range to each lander was obtained from four points at 500 meters from the drop location. This was done using the ranging feature on the lander's acoustic releases. This allowed an estimate of the actual position of the lander, given current and drift.

At the last station, VA2, the lander from VAC was recovered and the VEMCO and AZFP downloaded and mobilized on the VA2 lander.

Acoustic Zooplankton Fish Profiler (AZFP) Calibration – Jennifer Miksis-Olds

Three of the seven bottom landers were designed to include AZFP sensors. Overall sensitivity of the three systems were calibrated in the UNH acoustic tank prior to the cruise. The same three AZFP systems were calibrated at sea on 22 Nov 2017 at the Virginia Inter-Canyon (VAC) location. At sea calibration was necessary to 1) verify the overall transducer sensitivities after transport and 2) assess any impacts of depth on the transducers.

Each set of transducers was mounted to the bottom on the shipboard CTD rosette (Figure 3). A calibration sphere was suspended approximately 7-9 m below the transducers from a 3-point harness to center the sphere within the transducer beams. Four calibration casts were performed, each to a depth of approximately 200 m. A quick-look at the processed data shows that the calibration was successful. The sphere was captured in the AZFP sonar beams throughout the entire cast (Figure 4). The ocean bottom was visible as the CTD mounted transducers approached the seafloor (Figure 4). Additional statistical analysis is in progress to determine transducer sensitivity and depth dependence.

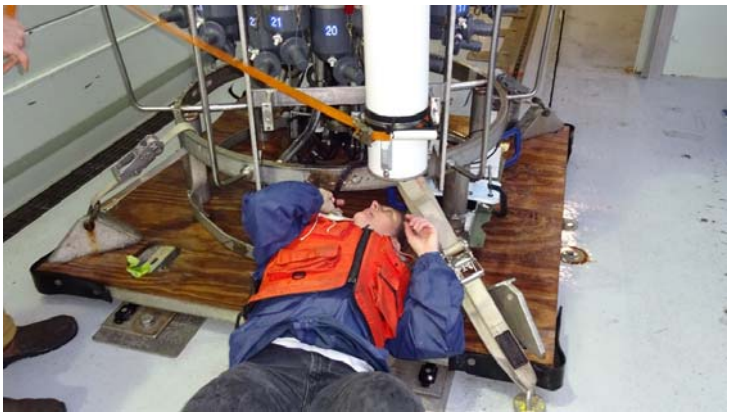

Figure 3. The AZFP transducers are being mounted to the bottom of the CTD frame by J. Miksis-Olds (left). AZFP transducers and battery pack mounted to the CTD frame (right).

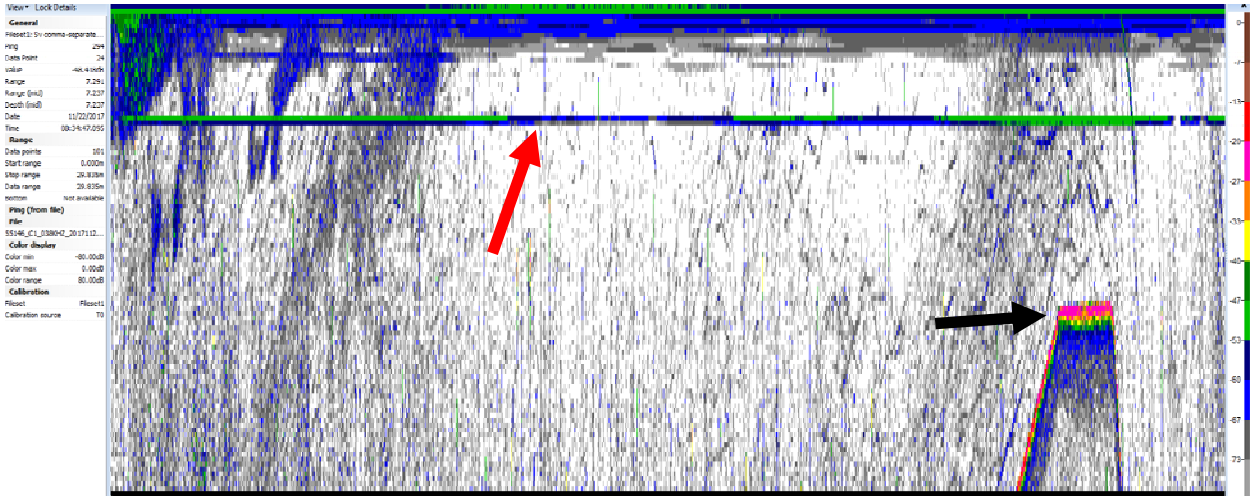

Figure 4. Calibration cast of AZFP (serial #55146) 38 kHz transducer to approximately 200 m depth. The red arrow indicates the echo of the calibration sphere suspended under the AZFP transducers at a constant depth of 7.3 m. The black arrow indicates the bottom reflection as the transducers on the CTD rosette approached the ocean bottom.

Propagation Loss Experiment – Kevin Heaney

The Propagation Loss (PL) survey portion of the ADEON Deployment Cruise consisted of 20 hours of low frequency acoustic transmissions (<2 kHz) in the vicinity of deployed ADEON landers. The technical objective was to characterize the propagation in order to provide confidence in the soundscape modeling to be performed in Phase IV. The 20 hours of transmission time was broken into 4 hour sections at 5 different times and locations. The transmission sites were Virginia Canyon (VAC), Wilmington (WIL), Savannah (SAV), Jacksonville (JAX) and again at Virginia Canyon (VA2). The marine mammal protocol involved 1 hour of intensive (3 person) marine mammal watch prior to transmissions. In the event of a marine mammal sighting, transmissions were ceased until the appropriate time had passed without a marine mammal in the area. This occurred both times at VAC. Transmissions were stopped at VAC after the sighting of a Leatherback turtle near the R/V Armstrong. There were no marine mammal sightings at any of the other locations. The source was calibrated using a monitor hydrophone 1 m from the source. The measured acoustic received level was also compared with the driving current for the J13. The source levels ranged from 164 dB re 1 μPa m at the lowest frequencies to 146 dB re 1 μPa m at the highest. PL transmissions were authorized under a Memorandum for the Record for the Office of Naval Research Acoustic Experiments in the Southeast Atlantic Outer Continental Shelf (U.S. Exclusive Economic Zone from Virginia to Florida) from the Navy and operated under the Navy's Protective Measures Assessment Protocol (PMAP).

Transmission Signals

The transmitted signal consisted of 14 10 s HFMs spanning from 70.154 Hz to 1781.8 Hz, alternating in up and down sweeps. Following the 140 s of sweeps, a 100 s of 4 sinusoidal tones (103, 351.49, 757.49, 1125.49 Hz) was transmitted. The sweeps were defined by lower and upper bounds listed below:

Table 3. Hyperbolic Frequency Modulation (HFM) parameters for 14 transmitted sweeps.

Sweep #	Start (Hz)	Stop (Hz)	Mean (Hz)
Sweep 1	88.388	70.154	79.271
Sweep 2	88.388	111.362	99.875
Sweep 3	140.308	111.362	125.835
Sweep 4	140.308	176.777	158.542
Sweep 5	222.725	176.777	199.75
Sweep 6	222.725	280.616	251.67
Sweep 7	353.553	280.616	317.08
Sweep 8	353.553	445.449	399.5
Sweep 9	561.123	445.449	503.286
Sweep 10	561.123	707.107	634.011
Sweep 11	890.899	707.107	799.001
Sweep 12	890.899	1122.46	1006.68
Sweep 13	1414.21	1122.46	1268.33
Sweep 14	1414.21	1781.8	1598.005

Transmission Site 1: Virginia Canyons (VAC)

November 23, 2017
The Marine Mammal Observation (MMO) watch was started at sunrise on Nov 23, 2017. There were marine mammals (Atlantic White Sided Dolphins) in the area. An hour after they left the area transmissions were started. Marine Mammal Watch Commenced: 11:30Z Transmissions Began: 14:10Z
Latitude: 37° 14.739' N
Longitude: 74° 30.841' W

Transmissions were stopped at 16:24Z after sighting a Leatherback Turtle. Transmissions resumed: 16:34Z

Transmissions Ended: 18:50Z Latitude: 37° 17.949' N
Longitude: 74° 31.408' W Range from Lander Posit: 5996 m

The calibration was measured with both the current driving the J13 and with the rms voltage received from the HTI Hydrophone, which was positioned 1m from the source. Using the J13 source cals (for a given Amperage) and the HTI sensitivity of -178 dB/V, the estimated source level for each of the 14 HFM tones and the 4 NB simultaneous CW tones is shown in Figure 5 below.

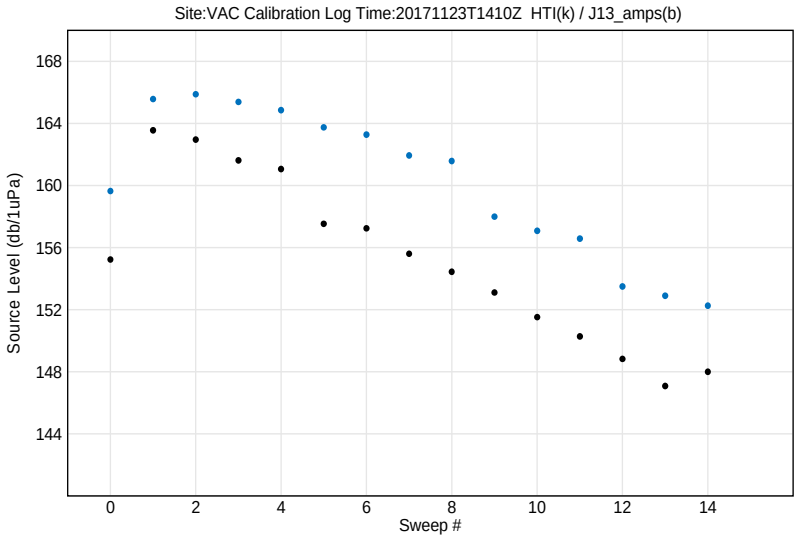

Figure 5. Calibration Curves for J-13 Source at VAC site.

Deployed J13 at Transmit Station 2, Wilmington. The calibration was measured with both the current driving the J13 and with the rms voltage received from the HTI Hydrophone, which was positioned 1 m from the source. Using the J13 source cals (for a given Amperage) and the HTI sensitivity of -178 dB/V, the estimated source level for each of the 14 HFM tones and the 4 NB simultaneous CW tones.

Transmission Site 2: Wilmington (WIL)

November 26, 2017
The MMO watch was started at sunrise on Nov 26, 2017. There were no marine mammals observed.
Marine Mammal Watch Commenced: 12:00Z Transmissions Began: 13:00Z
Latitude: 33° 35.1151' N
Longitude: 76° 27.047' W

Transmissions Ended: 17:00Z Latitude: 33° 38.431’ N
Longitude: 76° 27.4288’ W Range from Lander Posit: 7100 m

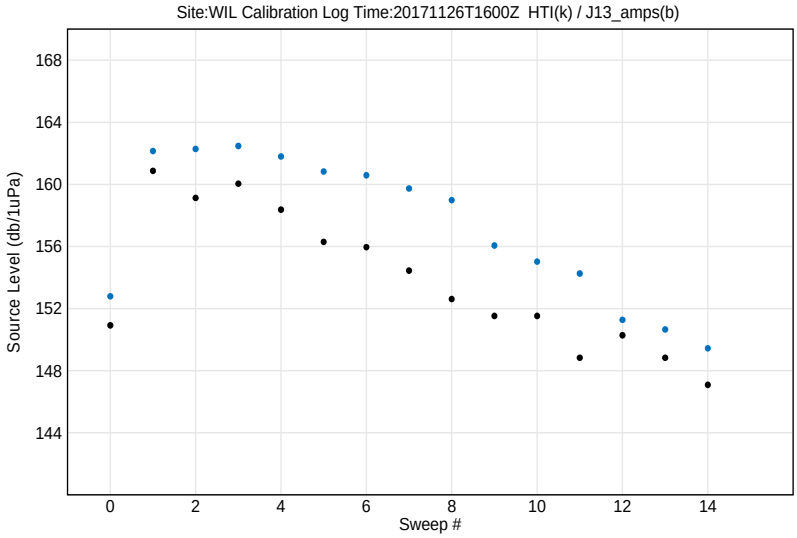

Figure 6. Calibration Curves for J-13 Source at WIL site.

Propagation modeling was performed for the VAC and WIL sites to estimate propagation range. The lander position was used as the source and the ship drift direction was set as the line of bearing. For this run, a 400-600Hz band incoherent Transmission Loss (TL) was computed and it is shown below. We anticipate a 70-75 dB/1μPa/Hz ambient noise. This result indicates that we should receive the signal with at least a 10 dB SNR for ranges out to 7 km.

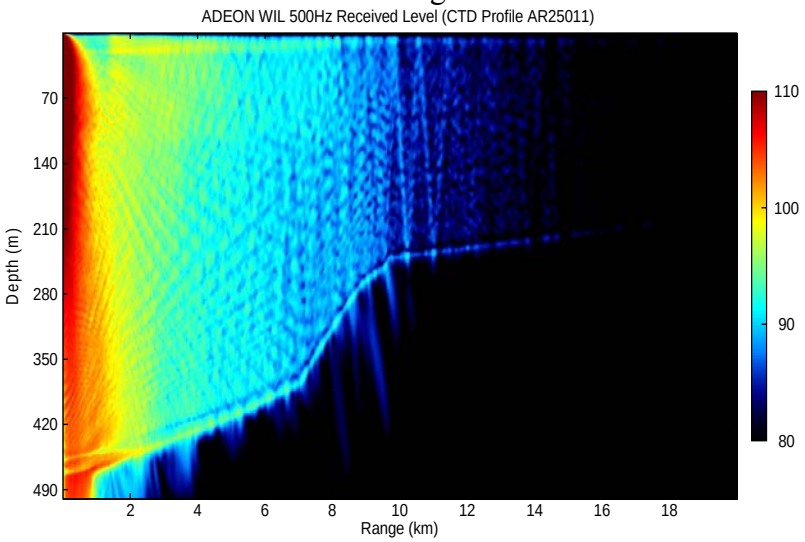

Figure 7. Incoherent TL computed across the 400-600 Hz band in the VAC/WIL region.

Transmission Site 3: Savannah (SAV)

November 28, 2017

The Marine Mammal Observation (MMO) watch was started at sunrise on Nov 28, 2017. There were no marine mammals observed. Marine Mammal Watch Commenced: 11:46Z Transmissions Began: 12:46Z

Latitude: 32° 2.573’ N
Longitude: 77° 20.850’ W
Stopped transmission to Transit 14:56Z Restarted Transmission 15:35Z
Transmissions Ended: 17:25Z
Latitude: 32° 3.912’ N
Longitude: 77° 16.224’ W
Range from Lander Posit: 7690m
The calibration was measured with both the current driving the J13 and with the rms voltage received from the HTI Hydrophone, which was positioned 1m from the source. Using the J13 source cals (for a given Amperage) and the HTI sensitivity of -178 dB/V, the estimated source level for each of the 14 HFM tones and the 4 NB simultaneous CW tones is shown in Figure 8 below.

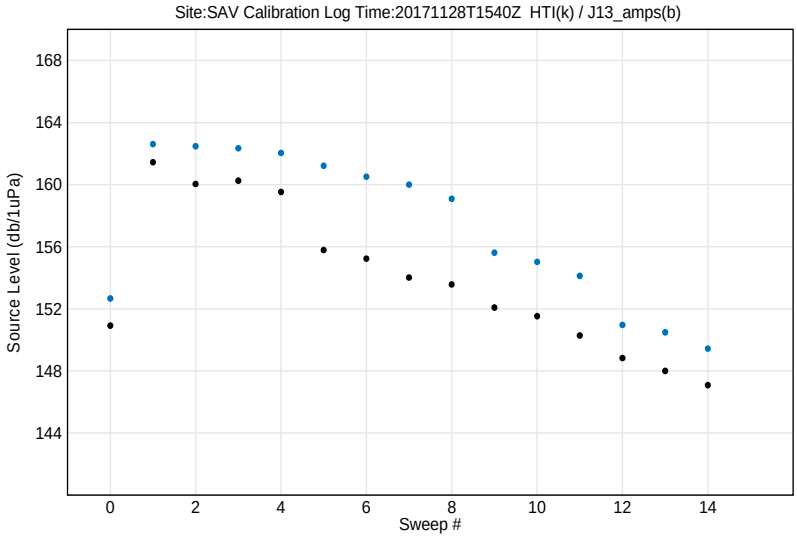

Figure 8. Calibration Curves for J-13 Source at SAV site.

Transmission Site 4: Jacksonville (JAX)

December 2, 2017
The tone set transmitted during the ADEON cruise was a 4 minute repeating sequence consisting of 14 x 10s HFM sweeps and 100s of 4 narrowband tones. The sweeps were frequencies 103, 305.45, 747.45 and . The HFM tones spanned from 70 Hz to 1880 Hz. In order to evaluate source level and signal type issues, a recording computer was connected to the hydrophone. The spectrogram of the transmitted tone, recorded through the monitoring hydrophone (at 1m) is shown below in Figure 9, along with the narrowband tone spectral power level in Figure 10. The current at JAX was close to 2 knts. The ship used it’s DPS to maintain it’s orientation to the wind/waves and drift with the water.

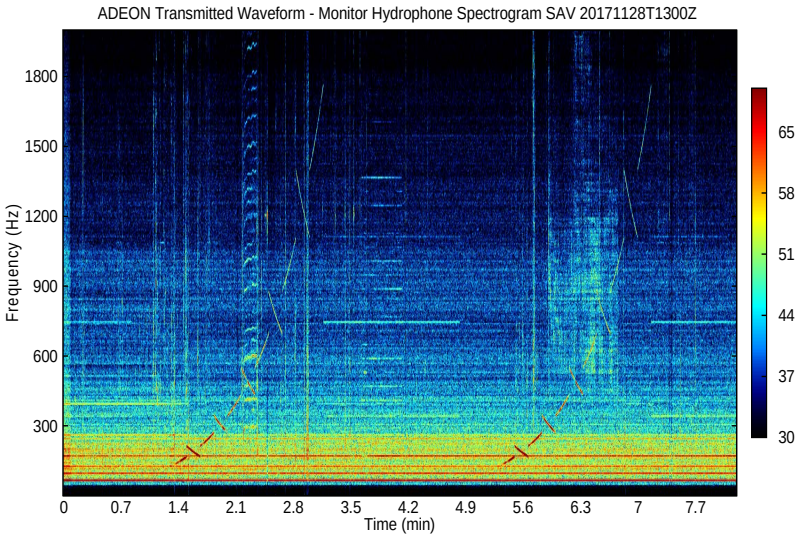

Figure 9. Spectrogram of ADEON Transmitted Waveform received on the monitor hydrophone.

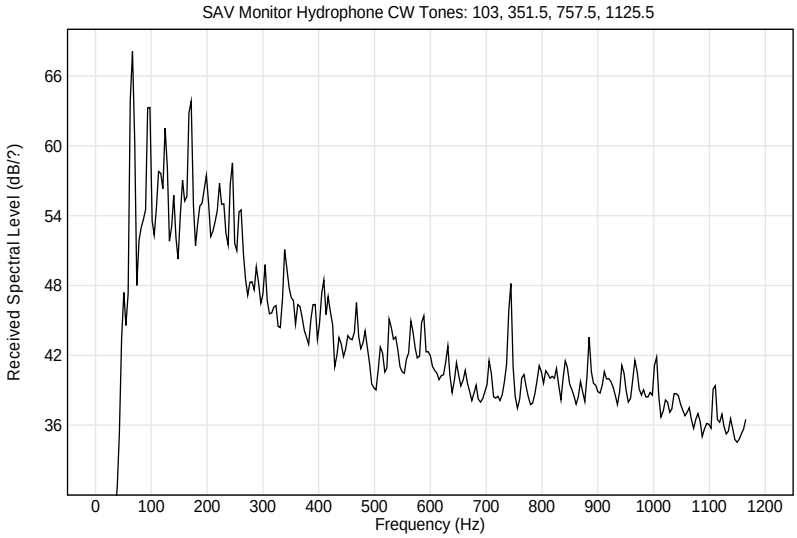

Figure 10. Spectrogram of ADEON Transitted Waveform received on the monitor hydrophone.

The calibration was measured with both the current driving the J-13 and with the rms voltage received from the HTI Hydrophone, which was positioned 1m from the source. Using the J13 source cals (for a given Amperage) and the HTI sensitivity of -178 dB/V, the estimated source level for each of the 14 HFM tones and the 4 NB simultaneous CW tones is shown in Figure 11 below.

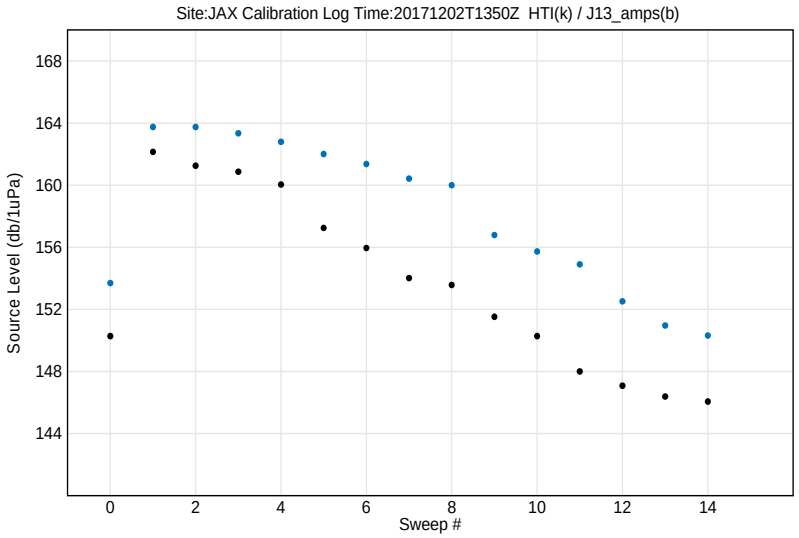

Figure 11. Calibration Curves for J-13 Source at JAX site.

The TL was computed for a 20 km due north run along the line drifted by the R/V Armstrong is shown below.

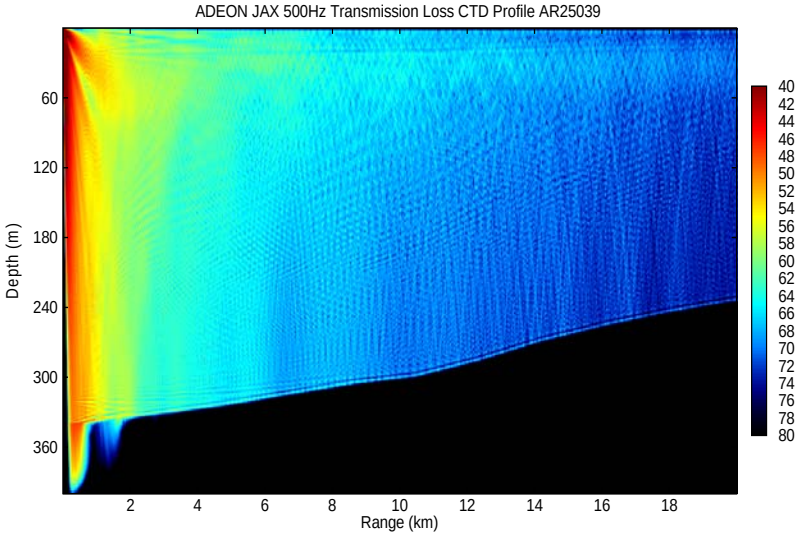

Figure 12. Incoherent Broadband 500Hz TL at JAX Site.

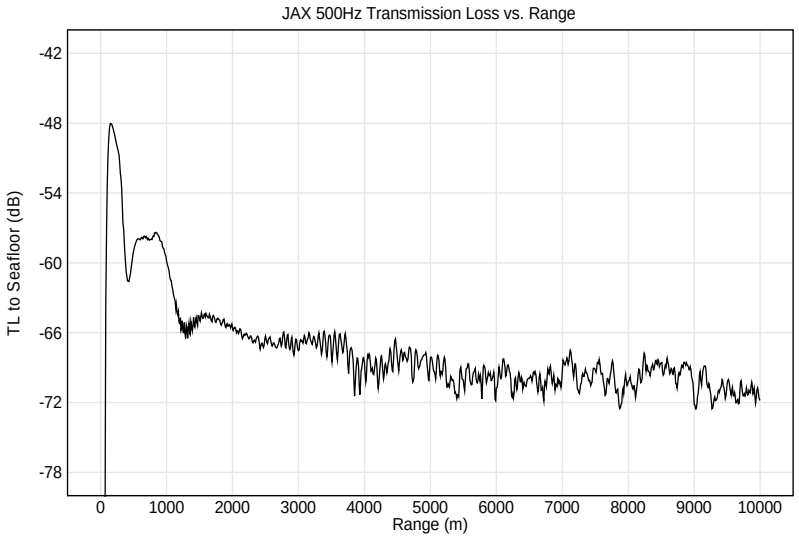

Figure 13. Surface suspended source to bottom mounted receiver along R/V Armstrong drift track.

The total transmission time for JAX was 4 hours with the transmission schedule as follows:
Marine Mammal Watch Commenced: 11:36Z Transmissions Began: 12:50Z
Latitude: 30° 30.02’ N
Longitude: 79° 59.958’ W
Transmissions Ended: 16:20Z
Latitude: 30° 38.7182’ N
Longitude 79° 58.1848’ W
Range 16319 m.
There were no marine mammals sited and no stoppage of transmissions.

Transmission Site 5: Virginia Canyons (VA2)

December 10, 2017
The final transmission site was a revisit to VAC. For this site, an emphasis was placed on low frequency transmissions, with the hope of receiving the signal at the CTBTO station HA08 off the coast of Ascension Island. The first 2 hours was the standard 14 HFM sweeps and the 3 line CW tones. For the last two hours, a LF signal set was put together.
Transmissions at VA2 began at 14:20Z
Longitude 74° 30.979’ W
Latitude 37° 14.595’ N
Sea State: 5
Winds 20 knots
The source level estimates from the monitor hydrophone (black) and the driving current of the J-13 (blue) are shown below in Figure 14. The source level ranged from 164 dB/1μPa for the lowest frequency sweep to 149 dB/1μPa for the highest frequency sweep.

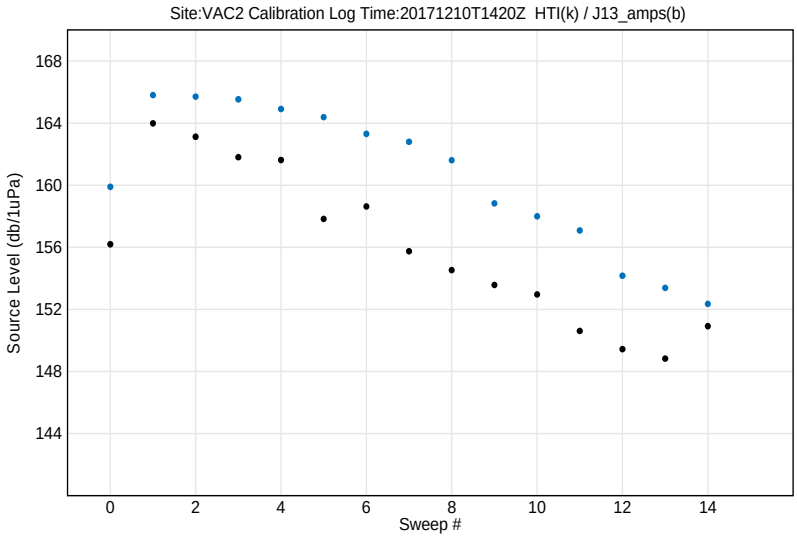

Figure 14. Calibration Curves for J-13 Source at VA2 site.

Transmissions were stopped for 30 min due to Atlantic whitesided dolphin observations near ship. (Stopped at 14:37) Transmissions Commenced at 15:09:10Z and went uninterrupted through 18:52:10Z The LF Signal Set, listed below, began at 16:55:00Z.
5 HFMs, Duration 30s Each
Sweep 1: 44.194 Hz -> 35.077 Hz Downsweep
Sweep 2: 44.194 Hz -> 55.681 Hz Upsweep
Sweep 3: 77.154 Hz -> 55.681 Hz Downsweep
Sweep4: 77.159 Hz ->88.388 Hz Upsweep
Sweep5: 88.388 Hz -> 111.362 Hz Downsweep
CW : 103 Hz for 90 seconds

With the LF signal set focused on the lower frequency band, there is more source level available from the J13. The calibration measurements from the monitor hydrophone and J-13 driving current are shown below in Figure 15.

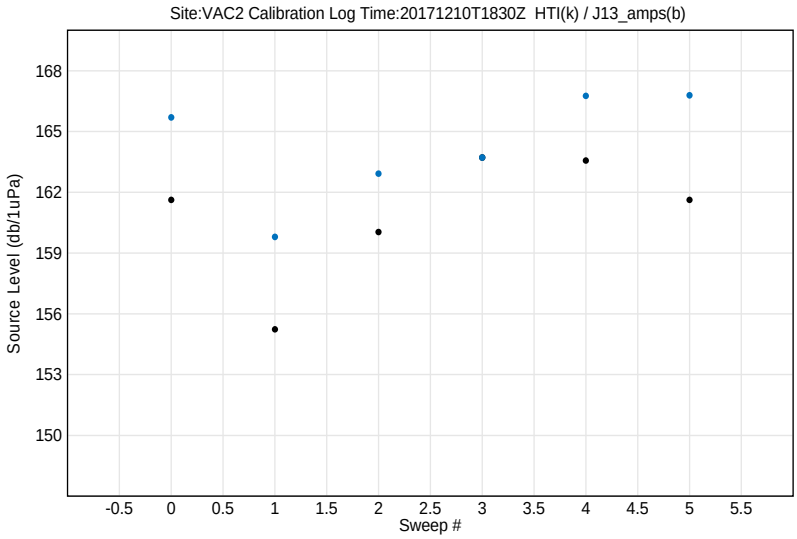

Figure 15. Calibration Curves for J-13 Source at VA2 site.

The source level of the J-13 for the LF set ranged from 156 dB/μPa (for the 40Hz sweep 1) to 163 dB/μPa for sweeps 3 and 4.

FINEX time/position Time: 18:52:10Z
Longitude: 74° 30.011’ W
Latitude: 37° 13.568’ N
Range: 1841 m.

Marine Mammal Observers (MMOs) – Jennifer Miksis-Olds

A dedicated team of MMOs conducted visual surveys from the ship during daylight hours while at the 7 ADEON lander locations. These observations were made to 1) provide a record and groundtruth for marine mammals sighted in the area for comparison to the lander passive acoustic datasets, and 2) to provide the required mitigation during the transmission of the propagation loss experiment. Over the course of the cruise, approximately 128 on-effort MMO hours were logged (Table 4). Many different animal groups were sighted in the area to include 2 species of sea turtles, 5 species of small delphinids, Risso's dolphin, pilot whales, minke whale, humpback whale, and harbor porpoise.

Table 4. MMO Effort Log for AR25 ADEON Cruise 1.

Date	Local Time Start	Local Time End	Hours Effort	Site
11/22/2017	6:54	17:04	10:10	VAC
11/23/2017	6:40	15:07	8:27	VAC
11/24/2017	6:40	16:49	10:09	HAT
11/25/2017				Transit
11/26/2017	6:30	17:32	11:02	WIL
11/27/2017	14:23	17:36	3:13	SAV
11/28/2017	6:29	17:15	10:45	SAV
11/29/2017	14:40	16:57	2:17	BLE
11/30/2017	6:30	16:30	10:00	BLE
12/1/2017	6:20	17:30	11:10	BLE/JAX
12/2/2017	6:36	17:45	11:08	JAX
12/3/2017	6:45	17:45	11:00	CHB
12/4/2017	6:27	9:30	3:03	CHB
12/5/2017				Transit
12/6/2017				Transit
12/7/2017	12:30	17:13	4:43	HAT
12/8/2017	6:15	16:01	9:46	HAT
12/9/2017				Transit
12/10/2017	6:45	17:23	10:38	VAC2
12/11/2017	6:35	17:12		VAC2
12/12/2017				Transit

Multiple Frequency Acoustic Echosounder Data – Joseph Warren

The RV Armstrong's EK80 system (Figure 16) was run continuously during the cruise with the 18 and 38 kHz transducers in narrowband (due to ship constraints) and the 70, 120, and 200 kHz transducers operating in broadband mode. Pulse lengths were 1024 microseconds and ping rate was set to maximum, except when in shallow (< 150 m) water or when sea state (and thus data quality) were poor. Ping rate was then set to 0.2 to 1 Hz.

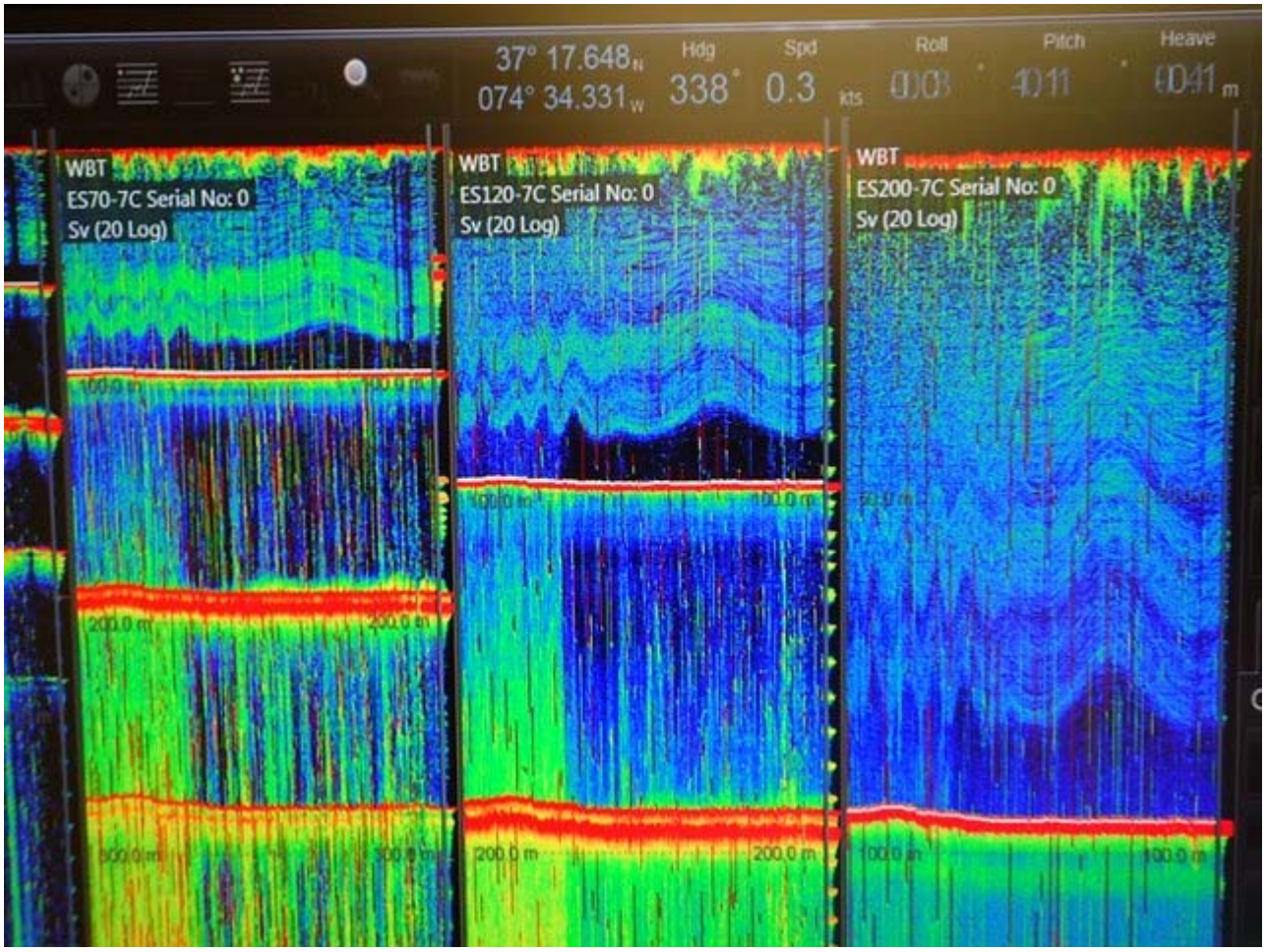

Figure 16. Example echogram from the ship's EK80 showing internal waves which were commonly observed during the cruise as the ship transited across the continental shelf.

At each survey site, a fine-scale acoustic grid (Figure 17) was conducted at a speed of 8 kn. Survey lines were adjusted for the direction of the sea state. At a few sites, the survey grid was run multiple times, either during the day and then the night, or separated by several days or weeks.

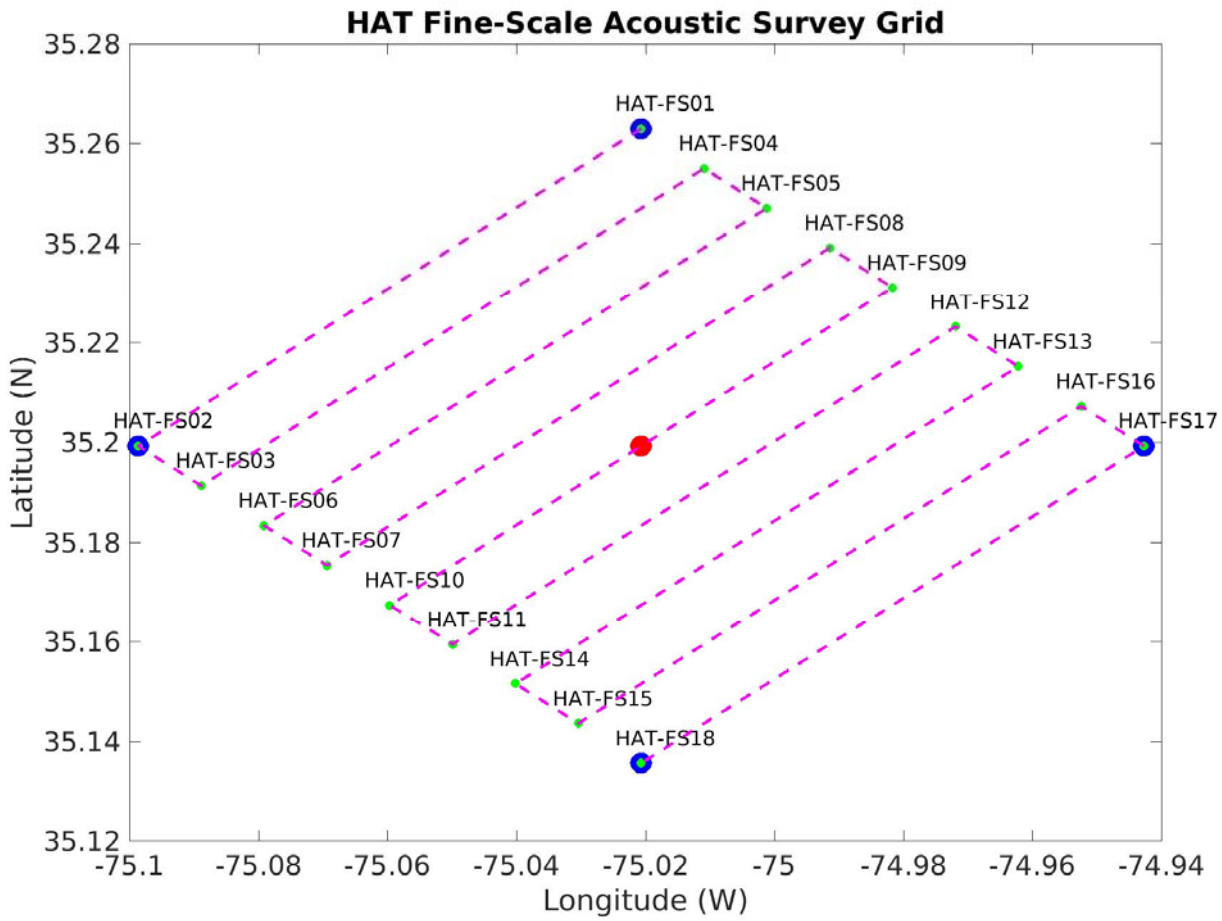

Figure 17. The grid acoustically surveyed at the HAT site. The red dot at the center represents the location of the bottom lander. The survey grid covers an area roughly 10 km by 10 km.

Net tow sampling – Joseph Warren

Biological specimens were collected at each site using two different nets. A 60 cm diameter, ring-net BONGO pair (one with 1000 um mesh, the other with 333 um mesh) was deployed at each site (roughly at the lander location) with a vertical cast to 100 m (Figure 18). Actual net depths may be slightly less than the wire out due to surface currents causing the tow wire to be slightly off-vertical. Zooplankton and larval nekton collected in the ring net were preserved in buffered formalin solution for post-cruise identification and enumeration. Unique or interesting specimens from these tows were occasionally photographed or preserved individually.

Figure 18. Bongo net being deployed for a vertical cast.

A larger net (5 m2 Isaacs-Kidd Midwater Trawl) was also deployed at each site (Figure 19), typically multiple times per site. One tow was done at the lander location and was targeted to sample the scattering layers observed in the water column on the ship's echosounder. Additional tows were conducted to sample the deep (> 750 m) scattering layers and to collect specimens from the mesopelagic region.

Figure 19. The Isaacs Kidd Midwater Trawl being deployed. Wire-out speeds were 20 – 40 meters per second, and haul-back speeds were 10 to 30 meters per second.

Animals from these net tows were preserved in formalin solution for post-cruise identification and enumeration. Selected individual animals were removed (noted on the tow data sheet) for photography (Figure 20), individual preservation, or for collaborators with the DEEP SEARCH project for stable isotope and DNA analysis.

Figure 20. Some of the animals collected by net tows during the cruise.

Biological Sample Collections for collaborators with the DEEP SEARCH project - Sebastian Velez

A series of biological samples were collected from this research cruise for the DEEP SEARCH Consortium. Tissue samples were collected for DNA Analysis from larger specimens while whole frozen individuals (both invertebrates and vertebrates) were collected for future isotope analysis. A total of 31 tissue samples were collected from a variety of different specimens, over half of which belonged to the family Myctophidae (Table 5).

Animals were collected for future isotope analyses whenever 5-10 individuals of a single species were found within a single trawl. A total of 371 individual animals were collected that met these criteria (Table 6). All invertebrates collected for isotope analysis were gathered at the VAC2 site over the course of four separate trawl samples. Many of the sampled species were caught at multiple sites save for a few odd species. All *Pronotogrammus martinicensis* (Roughtongue Bass) juveniles were caught off the trawls conducted at the JAX site as well as the *Coryphaena hippurus* (Mahi mahi) specimen.

It should be noted that the biodiversity of these hauls was much higher than what is represented in these collections as we were limited in our sampling by both size of the individual and number of individuals within a single species (Figure 21). Other encountered animals included members of the following taxonomic groups: Gempylidae, Lutjanidae, Acanthuridae, Pomacanthidae, Carangidae, Triglidae, Gonostomatidae, Tetraodontidae, Exocoetidae, Scorpaeniformes, and Lophiformes.

Table 5. Tissue sample collections from the ADEON Research cruise aboard the *R/V Neil Armstrong*.

Lowest Taxonomic Identification	**Common Name**	**Number of Tissue Samples**
Unidentified Fish	-	1
Gadiformes	Rat-Tail	1
Myctophidae	Lanternfishes	17
Evermannellidae	Sabertooth fishes	1
Stomiidae	Dragonfishes	1
Melamphaeidae	Slime heads	1
Bonapartia peladiota	-	2
Coryphaena hippurus	Mahi mahi	1
Gonostoma denudatum	-	1
Nemichthys sp.	Needle-nose eels	2
Nessorhamphus ingolfianus	Spoonbill eel	3

Table 6. Isotope specimens from the ADEON Research Cruise aboard the *R/V Neil Armstrong*.

Lowest Taxonomic Identification	**Common Name**	**Number of Frozen Specimens**
Amphipods	-	10
Copepods	-	16
Krill	-	30
Shrimps	-	60
Salps	-	60
Pyrosomes	-	10
Phronima sp.	Barrel Amphipod	30
Aulopiformes	Deepsea Lizard fishes	10
Pleuronectiformes	Flatfishes	12
Melamphaeidae	Bigscales/Slimeheads	5
Myctophidae	Lanternfishes	36
Argyropelecus sp.	Hatchet fish	7
Bothus sp.	Flatfish	28
Centropyge sp.	Angelfish	6
Cyclothone sp.	Bristlemouths	30
Pronotogrammus martinicensis	Roughtongue Bass	15
Stephanolepis hispidus	Sargassum Filefish	6

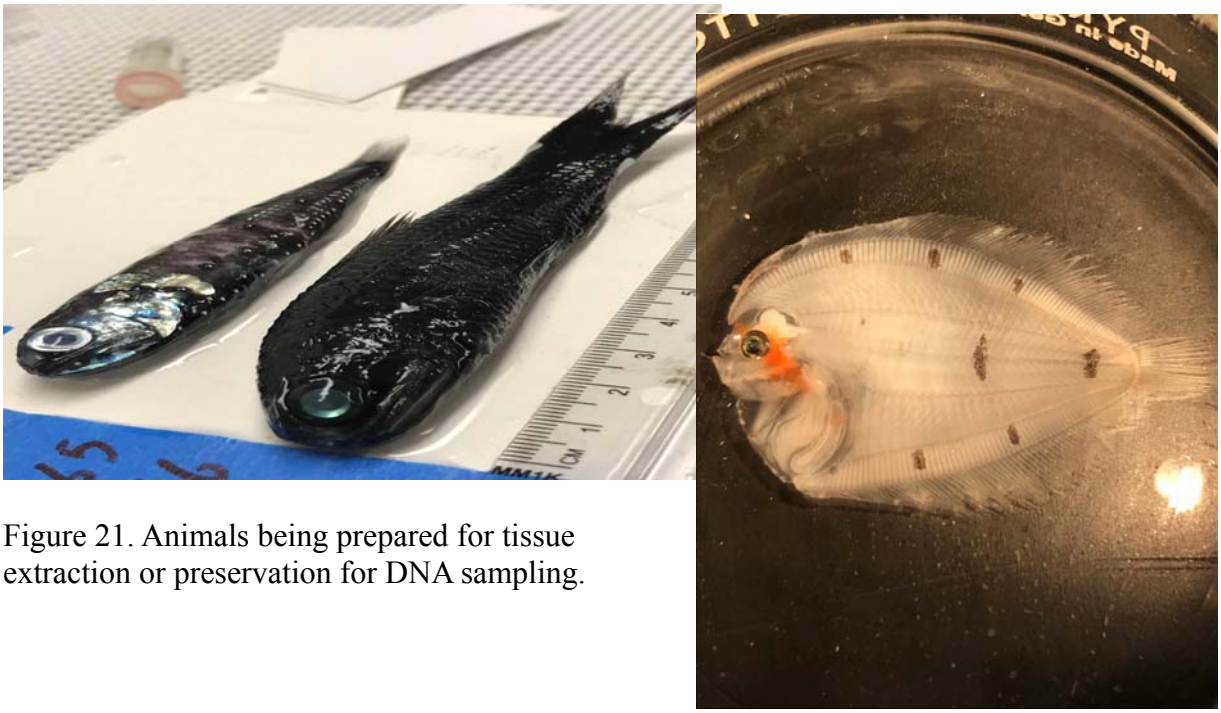

Figure 21. Animals being prepared for tissue extraction or preservation for DNA sampling.

Density Contrast Measurements – Hannah Blair

The density contrast (g) of an organism, or the ratio of animal density versus the surrounding seawater, is an important acoustic material property. Density contrast values are necessary components of acoustic scattering models, which allow for estimating zooplankton abundances from active acoustic data. Throughout the research cruise, shipboard density contrast measurements were conducted on zooplankton collected by net trawls.

Following each bongo and IKMT net trawl, zooplankton samples were inspected for animals suitable for taking density measurements. Where at least five animals of a taxonomic group that had not been measured previously were found in a sample, at least five and up to ten animals were randomly selected for density measurements. Taxa composing a large proportion of the trawl sample at multiple sites were periodically selected for additional density measurements. Occasional density measurements were also taken on animals even if there were fewer than five total in the sample. To maximize accuracy, measurements were conducted as soon after trawls were completed as was feasible.

Measurements were conducted using the titration method. This involved immersing animals in solutions of varying amounts of seawater and glycerin and adding small measured amounts of either fluid until the animal reaches neutral buoyancy, indicating that the animal's density matched that of the solution. Following each density measurement, all measured animals were photographed with a scale bar to animal length and shape can be measured post-cruise (Figure 22). Many of these animals were then frozen so that their masses may be measured after the cruise's conclusion.

Density measurements were made on a total of 272 animals. Taxa measured included: ctenophores, jellyfish, chaetognaths, *Phronima* spp. and other amphipods, copepods, decapods (shrimp and various larvae), stomatopods, euphausiids, pteropods, squid, salps, pyrosomes, and various fish (Myctophidae, Gonastomatidae, Stomiidae, Melanphaidae, Perciformes, Pleuronectiformes, Aulopiformes), and elopomorph larvae (leptocephali).

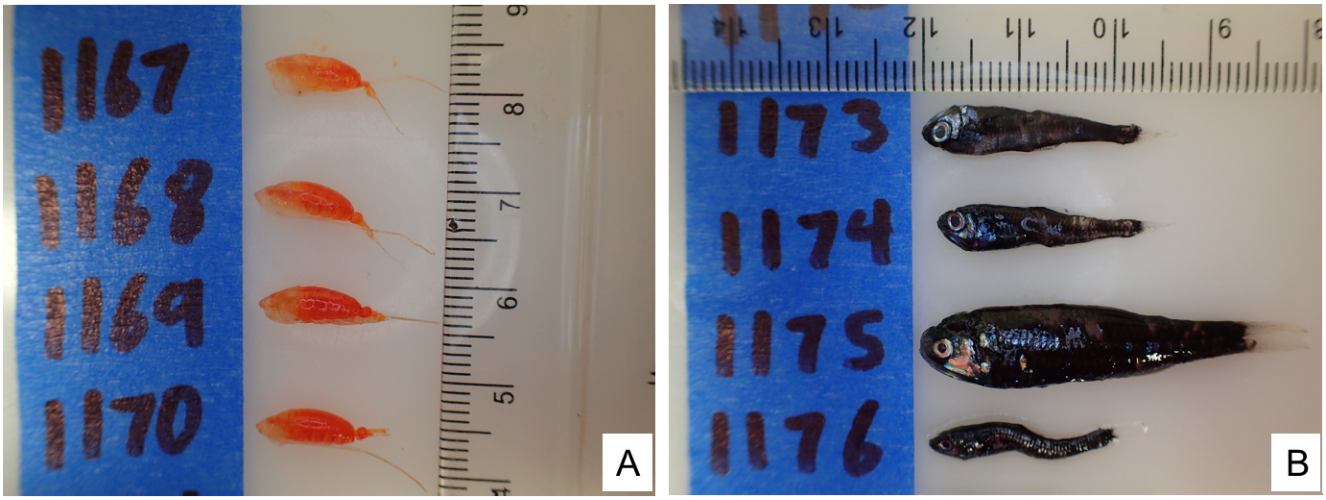

Figure 22. Four large copepods (A) and four myctophid fish (B) of various sizes photographed for length and morphometry measurements following density measurements.

Target Strength Measurements of individual organisms – Brandyn Lucca

The *ex situ* target strength (TS), which is the logarithmic measure of the acoustic cross-section of a target, of several types of organisms were measured. These TS estimates provide valuable acoustic data for single organisms that can be used to improve animal density estimates and target identification of acoustic backscatter in the water column. All TS experiments were conducted in a 44 gallon Rubbermaid aquarium with aluminum brackets fitted with two broadband polyurethane transducers (Figure 23). These transducers pinged at both discrete frequencies (38, 50, 65, 70, 120, 160, 192, and 200 kHz) and broadband sweeps (15-85, 15-40, 41-55, 56-70, 71-85, 110-230, 110-140, 141-170, 171-200 and 201-230 kHz).

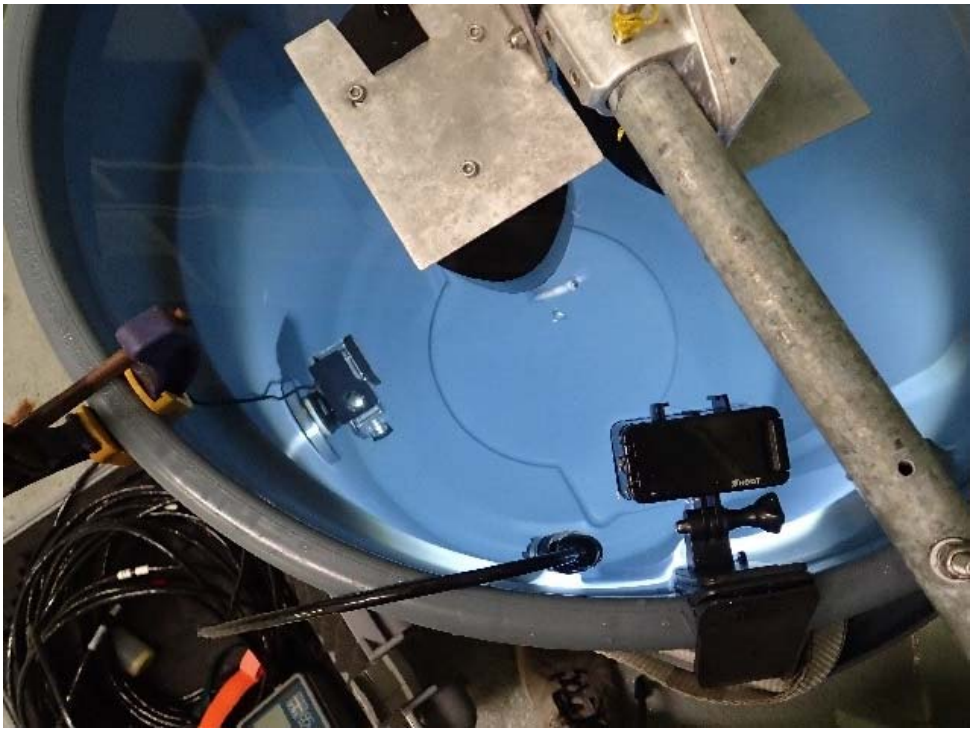

Figure 23. Aquaria set up of broadband transducers, underwater camera to monitor the orientation of the animals, LED lights to increase visibility, and a YSI 85 probe to collect real-time temperature and salinity data which affect the sound speed velocity in water.

All animals used in the experiment were collected from various Isaacs-Kidd Midwater Trawls (IKMTs) which had a 1 mm mesh cod end. Broadside and ventral photographs of all animals were taken prior to any experiments to help parametrize theoretical TS measurements which are, in part, a function of animal length, height, width, and overall shape (Figure 24). A sub-sample of animals were frozen for future measurements (e.g. mass, calorimetry).

Figure 24. Examples of two bristlemouths caught during one of the deep IKMT deployments.

Animals were tethered to monofilament fishing line (3.5 lb, 0.007 in thickness) using a single loop around their respective midsections at an approximate depth of 34 cm. A GoPro camera was set up to provide a live-feed of each animal's position in the trash can and to provide photographs that can be used to measure tilt angles relative to the water surface (Figure 25). Images and video were captured at a minimum of 30 FPS since a ping rate of 30 Hz was used.

Figure 25. Photograph of a tethered larval squid caught in a larval net on 25 November 2017.

In addition to the TS experiments, *h*-measurements were also made. The *h*-value is the speed of sound of an animal(s) relative to empty seawater and is an important metric for understanding how sound scatters through animals with different material properties. These measurements comprised loading a PVC t-joint (volume ~ 76 ml) with animals and clamping two 192 kHz brass transducers to each end. The entire apparatus was then placed into a tote filled with ambient seawater. Both *ex situ* TS and *h*-measurements were done on numerous animals which include krill, shrimp, and squid (Table 7).

Table 7. Number of TS and *h*-measurements made for different groups of animals.

Animal	**TS**	***h*-measurements**
Squid	2	0
Shrimp	5	0
Krill	0	3
Myctophids	4	0
Pyrosome	1	1
Cyclothone spp.	1	0
Bristlemouth	1	0
Salps	0	5
Total	13	9

Single Point Interface Roughness Inferring Transducer (SPIRIT) - Calder Robinson

High resolution, broad-spectrum ocean surface behavior captured during transmission loss experiments can be assimilated into transmission models to evaluate the effect of surface scattering. The SPIRIT sensor package, by virtue of being mounted to the ship (and thus sound source) is in a unique position to provide this information with regards to the local environment. SPIRIT is composed of an ultrasonic (95 kHz) rangefinder (8° conical beam angle), 9-axis IMU, GPS, and data logger, all mounted above the surface of the ocean on a telescoping boom (12' long) from the side of the ship (Figure 26). SPIRIT measures the distance to the water surface while collecting position, 3-axes acceleration, rotation rate, and magnetic field strength of the sensor at 10Hz; aiding removal of ship movement post deployment and creating a time series of surface height.

The sensor was deployed in parallel to the transmission loss experiments performed by Dr. Kevin Heaney (OASIS). SPIRIT deployments lasted four hours at five sites (Table 8) while the ship was allowed to drift with the current. It should be noted that the four hours represent a cumulative transmission time, as occasional marine mammals forced the halt of transmissions until they cleared the area (~30 minutes). Initial damage to the sensor during transit to WHOI forced the sensor to operate directly from a 12 V battery rather than 15 V from the integrated DC-DC converter. This may have range finder calibration implications. Large waves forced the sensor to be mounted higher on the hull after the first deployment. Ship influenced waves appeared to extend further than the sensor could reach, potentially confounding some data.

Figure 26. SPIRIT deployed with guy lines on the side of RV Neil Armstrong.

Table 8. Date, Location, Duration, and comments on SPIRIT deployments.

DD-MM-YY	Location	Total Duration	Comments
23-11-17	VAC	4:38	Waited for mammals
26-11-17	WIL	4:00	Moved SPIRIT higher
28-11-17	SAV	4:38	No current, had to move
02-12-17	JAX	4:00	
10-12-17	VA2	4:36	Delayed start and pause for mammals

Recovery of Autonomous Sailboat Ada

During the cruise, we noticed a sail vessel (missing its mast) adrift. After determining that the vessel was missing and that the University of British Columbia students who had built it were seeking its return, the ship's captain and crew staged a recovery operation to secure the vessel and bring it aboard the RV Neil Armstrong (Figure 27). This generated several news stories, especially in the Canadian press.

Figure 27. The sailboat Ada after being recovered at sea during our cruise. The sail vessel was brought back to Woods Hole and the University of British Columbia students who built it were working on transporting it back to Canada