R/V Endeavor Cruise #487 'Georges Bank Krill'

Cruise Report

October 28 – November 6 2010

Report prepared by Gareth Lawson, Peter Wiebe, Cynthia Sellers, Philip Alatalo, Wu-Jung Lee, Nicholas Woods, Kaylyn Becker, Reny Tyson, Kelly Kleister, Nancy Copley, and Timothy White.

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Biological and Chemical Oceanography Data Management Office
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
http://bcodmo.org/

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"*Biological and Physical Determinants of Euphausiid Aggregation, Behavior, and Interaction with Higher Predators at an Abrupt Topographical Feature in the Gulf of Maine*"

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1. Acknowledgements

The success of this cruise would not have been possible without the efforts of the Endeavor's captain, officers, and crew and we are very appreciative of their hard work. The extremely capable assistance of URI Marine Technician Dave Nelson was likewise much appreciated. We are also grateful for the efforts of the University of Rhode Island's ship support group prior to the cruise with respect to planning and installing all equipment. This cruise was supported by NSF grant OCE-0928801.

2. Background

The physical and biological forces leading to variability, or patchiness, in the distribution of zooplankton represent a long-standing problem in biological oceanography. The interaction of active vertical movements with the flow fields typical of regions of abrupt topography is thought to be an important mechanism for the generation of zooplankton aggregations, and this project addresses gaps in our understanding of the formation and maintenance of euphausiid aggregations in such regions. Euphausiids (krill) are an important group of crustacean zooplankton in North Atlantic pelagic ecosystems, and represent an interesting model species for the study of zooplankton patchiness due to their strong swimming capabilities and active aggregative behaviors.

The goal of this project is to examine the biological and physical processes leading to the aggregation of zooplankton, particularly krill, on the northern side of Georges Bank and southern Gulf of Maine, as well as the interaction of these aggregations with higher predators, including fish, marine mammals, and seabirds. The project consisted of two cruises, EN484 in late September when herring in the area, which we hypothesized to be the main predator, were expected not to be feeding on the krill due to their being pre-spawning; and then EN487 in late October at which time we anticipated that the herring would have spawned and would be feeding on the krill. This thus provided a 'natural experiment' varying the levels of predation pressure. This is an NSF-funded project with WHOI scientists Gareth Lawson, Peter Wiebe, and Andone Lavery as PIs.

Each cruise involved an ambitious set of science objectives, including the completion of two planned 'mapping' surveys of a regular transect grid to identify zooplankton aggregations, with each mapping survey followed by a 'tracking' survey along adaptively-chosen transects examining individual aggregations. Underway instruments deployed included a deep-towed broadband acoustic towed body, a surface-towed multi-frequency acoustic sled, and the ship's hull-mounted ADCP for currents. During daylight hours, visual observers were to survey surface-associated top predators and test an automated panoramic camera system. At periodic stations, underway activities were interrupted for CTD casts (for hydrography), Video Plankton Recorder (VPR) profiles, and/or MOCNESS net tows (to ground-truth the acoustic data). Each of these latter three instruments was deployed (separately) via the stern A-frame, with the intent of keeping the two acoustic bodies in the water at the surface. A calibration of the deep-towed acoustic system relative to depth and tests of a new LED-based strobe light system on the MOCNESS were also planned. During EN487 our survey work was coordinated via email and radio contact with Leg III of the concurrent bottom trawl survey on the FRV HB Bigelow conducted by the Northeast Fisheries Science Center (NEFSC), such that we will later be able to draw upon the results of his pelagic trawls to determine the size and kinds of fish present, as well as whether or not euphausiids were present in their stomachs.

3. Cruise Objectives

The central goal of this cruise was to quantify the distribution, abundance, aggregation structure, and interaction with higher predators, of euphausiid aggregations at a study site along the northwestern flank of Georges Bank. The specific objectives included:

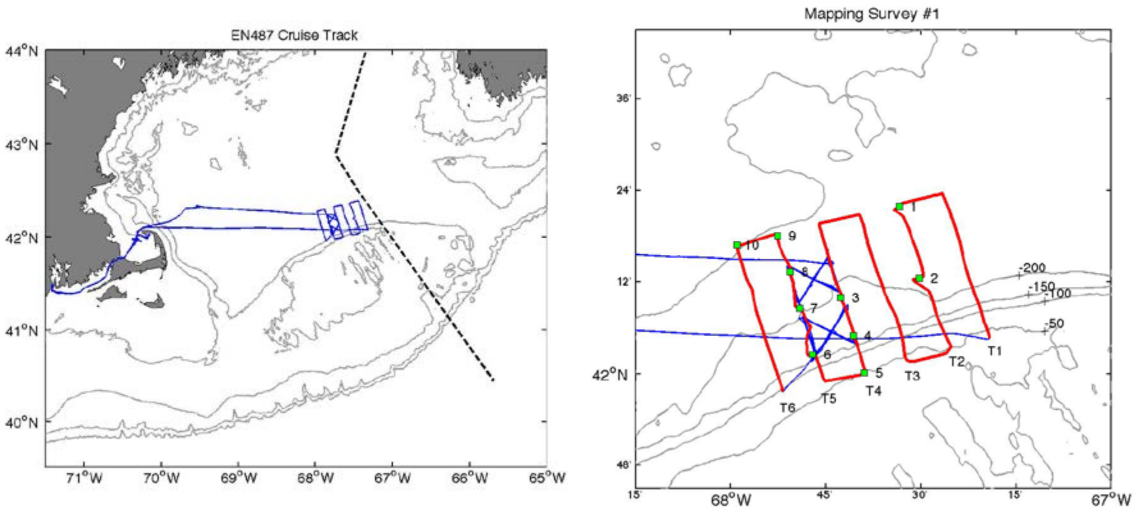
1. To survey hydrographic conditions via underway sampling systems and CTD deployments at a series of stations along both the mapping and tracking survey lines.
2. To characterize the flow field via ADCP data collection.
3. To conduct VPR casts to quantify the vertical and horizontal distribution and abundance of euphausiids and other zooplankton.
4. To conduct tows with a Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) at a subset of stations to quantify the vertical and horizontal distribution and abundance of euphausiids and other zooplankton.
5. To test the efficacy of an LED-based strobe light system mounted on the MOCNESS for mitigating krill avoidance behaviors.
6. To preserve net samples of euphausiids and other zooplankton for later analyses of taxonomic composition.
7. To preserve zooplankton for later genetic/genomic analyses by colleagues at the University of Connecticut.
8. To collect multi-frequency acoustics continuously along-track and at stations from the surface using a towed body to characterize the distribution of zooplankton, especially euphausiids, across spatial scales.
9. To collect broadband acoustic data via a towyoed package in order to assess the utility of such data for providing enhanced information on the taxonomic composition of scatterers present, and ideally enhanced information on the abundance, size, and distribution of euphausiids.
10. To conduct visual surveys for macrofauna including seabirds, marine mammals, and surface-associated fishes.

4. Survey Design

A tentative study region north of Cultivator Shoals, just beyond the Great South Channel, had been selected at the time of proposal submission based on acoustic and net samples made during previous years by our collaborator Dr. Jech in the course of the NEFSC fall acoustic and pelagic trawl surveys for herring. Based on observations made by Dr. Jech during Leg I (Sept 7-17) of the 2010 herring survey of this region on the FRV Delaware II, just prior to EN484 the exact study site ultimately examined was shifted slightly towards the northeast to a region centered at 42°N 67°30’W, extending from approximately the 50-m depth contour to depths >200 m in the southern Gulf of Maine (Figure 4.1).

The planned design was to re-occupy the same region as surveyed during EN484 and again to conduct an initial 2-day mapping survey to map out the distribution of krill, followed by a 2-day tracking survey where the vessel would remain with a particular aggregation. This would be followed by a second mapping-tracking pair for the remaining 4 cruise days. As during EN484, however, logistic constraints including weather and slow survey speeds required the scope of the survey effort to be reduced.

The ultimate survey design therefore involved an initial mapping survey along 6 transects running across isobaths from the ca. 50m contour towards the northwest into the Gulf of Maine (Figure 4.1). Upon completion of this survey, a tracking survey of a 5nm x 5nm region was repeatedly surveyed via a ‘bowtie’ pattern. Unlike during EN484 where the tracking survey was followed by a second, abbreviated, mapping survey, during EN487 the first tracking survey was followed by a second tracking survey at a nearby location.



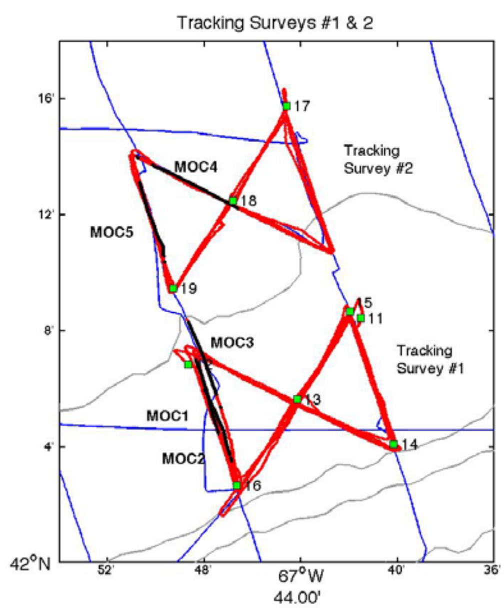


Figure 4.1. Clockwise from top left: EN487 cruise track, mapping survey #1, and tracking surveys #1 and 2. Blue lines show ship's track. Red lines show survey locations with transects labeled by number. Black lines show MOCNESS tow locations. Green boxes indicate stations.

5. Cruise Narrative

Summary

For the most part, the science objectives were met though to a lesser extent than on EN484 due to worsened weather. The cruise departure date was delayed by a day due to malfunctions with the surface-towed acoustic system's deck unit. The ship operator generously accommodated us by extending the return date by a day, however, so the day was not lost. The malfunctioning deck unit was repaired by the manufacturer and transferred to the Endeavor via small vessel off Provincetown. While waiting for that unit in Cape Cod Bay we were able to calibrate the deep-towed system at a series of depths, something we had not been able to achieve on the previous cruise. Once at the Georges Bank study site, work began with an initial mapping survey along a regular series of six transects running across the slope of Georges Bank and into the Gulf of Maine, each 20 nm in extent and spaced every 5 nm along-slope. This was the same survey grid sampled during EN484. On every second transect, underway surveying was interrupted at 5 regularly-spaced stations for profiles with a Video Plankton Recorder (VPR) – CTD package.

With a new tow boom manufactured by the WHOI shop between the two cruises we were able to tow the surface-towed body in even the worst sea states experienced during the cruise. Having this capability (and having that system's deck unit repaired and operational) was crucial because we were unable to deploy the other, deep-towed, acoustic system until the fourth day on the Georges Bank study site. This was due to a combination of bad weather and because even at the maximum outboard extent of the J-frame, unfavorable currents relative to the vessel's course would push the body and tow cable up against the ship. Also due to the bad weather, the first net tow to confirm the presence of krill wasn't conducted until the third day of the survey. Otherwise, the acoustic surveying went as planned, and we were again very pleased that at stations we were often able to deploy three instruments at a time (port-side, stern, starboard-side) as intended, in order to collect co-located data.

During surveying, the data from the acoustic sensors again indicated the presence of a persistent layer of krill throughout much of the surveyed region, along with fish-like scattering (likely herring) in certain regions, particularly next to the Bank. Net sampling confirmed that krill were the source of this scattering. Underway data collection with the ship's ADCP also went very smoothly. Due to the excellent support of Jules Hummon at the University of Hawaii (UH) and the user-friendly UH Data Acquisition Program we were able to synchronize transmission from the ADCP with our own scientific echosounders; this was necessary because the three instruments overlapped in frequency. During daylight hours, visual surveying for seabirds was very successful and numerous species of diving birds (e.g., gannets, dovekies) that had not been present in the region during EN484 had by now moved in. Due to often rough conditions, visual surveying for marine mammals was mostly not possible.

Examination of data collected during the mapping survey led to the identification of a box 5 nm in across- and along-track extent to be targeted by a 48-hour tracking survey, situated in a region of high krill- and fish-like acoustic scattering along the same transect as where the tracking survey was conducted during EN484. A 'bow-tie' pattern covering the tracking survey box was repeatedly transited with the acoustic systems, punctuated by occasional adaptive VPR casts based on real-time examination of the acoustic data. Two net tows were also conducted. Malfunctions with the strobe light system precluded any tests of its efficacy of the sort conducted during EN484. As possible given sea states, top predator surveying continued during the tracking survey. Successful coordination with our NEFSC collaborators was also achieved: mid-way through the tracking survey the FRV Bigelow conducted a bottom trawl directly through our survey box, sampling a large number of herring. Upon completing the initial tracking survey a second, abbreviated, tracking survey was conducted 2 miles to the north in a region where the acoustic data suggested fewer fish were present, making for an interesting comparison to the first tracking survey.

Advancing bad weather led to a departure from the study site a day early. The final science day of the cruise was spent in Cape Cod Bay where we attempted to do additional calibrations of the deep-towed acoustic system and MOCNESS flowmeter. Rough sea states coupled with an abundance of fishing gear made these efforts a qualified success.

The 11 member science party was again divided into an eight-person zooplankton team, who handled the various acoustic/optical/environmental instruments and will conducted operations around-the-clock, and the three top predator observers, who only worked during daylight hours and only when the vessel was underway (i.e., not on station). The zooplankton team was divided into two 12-hour watches of four with

Lawson and Wiebe as watch leaders for the day (0530-1730) and night (1730-0530), respectively. Many of the science party had participated in EN484 and so were highly familiar with the work and the science party was able to complete all of the necessary tasks towards achieving the cruise's scientific objectives. The URI ship's operator kindly provided an extra A/B (for a total of 4) and by their pulling extra shifts we had two A/Bs on watch at all times. This allowed one of them to be in the doghouse running the winch during towing operations, which often went on for many hours at a time when towing the broadband deep tow system. Dave Nelson the marine technician kept irregular hours and so was on-hand for all of the MOCNESS tows and as needed for other operations, including emergency instrument repairs.

Monday October 25, 2010

The initial set-up team (Lawson, Wiebe, Lavery, Copley, and Becker) spent the day in Narragansett loading and setting up equipment. Dana Hackett arrived with the 20' WHOI flatbed truck around 1000. Off-loading the truck and loading the ship went smoothly. The electronic gear (deck units, computers, etc) and other things that had to be kept dry were transported in Nancy's and Andone's vans. We also loaded the MOCNESS and associated supplies/parts that we had left in RI between the last cruise (EN484) and the present one.

By 1600 the team had loaded and installed the majority of the gear. Pat the boatswain and the ABs installed the new tow boom for the Greene Bomber (aka the Cannon) which looked nice and strong and up to the task of towing the fish in the rougher seas we saw this cruise. The HammarHead was buttoned up, having had all of its connectors lubed and checked. During the last cruise, wire #2 on winch #1 (the winch we used with the HammarHead due to its having a short length of wire, ca. 700m, due to some of the original wire having been cut off after the Gulf of Mexico cruise) had been damaged. We therefore used wires 3 and 4, but wanted to check that we could still achieve the necessary bandwidth with those wires and that they weren't also damaged. The bandwidth tests all went fine and we were able to sample to 75/75/50m on the three sub-channels as on the previous cruise. The nets and other parts (flowmeter, sensors, etc) were also attached to the MOCNESS and a basic communications test went well.

Tests of the HTI acoustic system in the Greene Bomber did not go very well. We wired the system up as on the previous cruise (deck unit mid-way forward in the main lab, data cable out the aft stuff hole, with the end of the cable sistered to the tow line). A rub test did not produce any signal, however. The displays were in fact blank, with not even any TVG-amplified noise. Looking at the datafiles the voltages were all zero. The system had worked fine on Friday when we last used it at WHOI. Phone calls to HTI led to a number of tests involving removing and inspecting the filter and monitor/control boards, looking for damaged/scorched/loose/unseated components. None of this solved the problem, but suggested to the HTI support team a problem with the Monitor control board. They therefore packed up a new board for overnight delivery.

Tuesday October 26, 2010

Further work on assembling gear and trouble-shooting the HTI system got underway early. Final assembly of the MOCNESS was complete by mid-morning. Wired up through winch #2 it communicated fine (using the shield and one conducting wire). The VPR was assembled and communication of the CTD was tested (also through winch #2, using the other 2 conducting wires). In order to get all of the data through, the baudrate had to be set to 1200 (from an initial 6400 in the original config file) and the sample averaging was kept at 2 (i.e., 2 samples per second since the system samples at 4 Hz). Everything seemed to work fine, except the bottom switch, which is supposed to register 4V when open (ie with the weight hanging free below the cage), but was registering 0V all of the time.

The new monitor/control board arrived from HTI around 1030 and tests immediately got underway. Every permutation we tried though of boards (i.e., the Bomber filter board, the BIOMAPER filter board, the Bomber monitor/control board, the new board, the Bomber ‘chip on disk’ mounted on each of the different monitor/control boards) still resulted in nothing. The eventual decision was for HTI to ship us overnight a complete new M244 deck unit for 0930 delivery, thereby delaying our departure from its scheduled 0900 time.

In the meantime, science party personnel were arriving, getting to know one another, and installing their gear. The initial science party meeting originally scheduled for Tuesday afternoon was postponed in order to focus on the HTI system.

Wednesday October 27, 2010

The first order of business Wednesday morning after breakfast was a meeting of the science party to review basics of life at sea, WHOI and URI policies on harassment, watch duties, etc. Shortly after the meeting the new HTI deck unit arrived and we got to work on further testing, hoping to get the system ready for an 11am departure. The new M244 deck unit did not work, nor did any combinations attempted of the various boards, chips, and chassis. The departure time kept getting postponed until 3pm at which time we decided to postpone until Thursday. Sam DeBow the URI ship scheduler kindly suggested that we could add a day at the end of the cruise to compensate. The team continued working on the M244 until 5pm, at which time we decided to send both deck units to Seattle for HTI to work on them. In the meantime, we planned to sail first thing Thursday morning, with the hope that HTI would get the system fixed before we left the coast.

The problem with the VPR bottom switch was addressed by increasing the number of samples averaged over. The bottom switch voltage apparently is the last part of each message, and although temperature (early in the message) was making it up the wire, the voltage apparently was not.

Thursday October 28, 2010

The ship departed Narragansett as scheduled at 0900, albeit without the HTI echosounder. Seas were relatively calm in Narragansett Bay but became a little rougher in Long Island Sound and beyond as the winds were from the SW and reasonably strong. Many of the science party were feeling a little queasy. Overnight and early in the morning we had contacted Jesus Pineda and Vicke Starczak about using the departmental Biosonics DT-X 120/200 kHz system as a replacement for the HTI. The Biosonics system is sub-optimal as it doesn’t use a chirp pulse and so has limited range and only has the two frequencies. It seemed better than nothing so, and so a transfer was arranged for Buzzards Bay. Jay Sisson, Ed O’Brien, and Jeff Eckblaw came out on the Mytilus, pulled up alongside of us just outside of the shipping channel, and we got the Biosonics transducers, cable, and deck unit on board successfully.

Shortly after, however, we got a call from HTI saying that they had identified the problem with the M244 – a 5V power supply on the backplane had blown, which had somehow fried the disk on chip (ie the chip that houses the C and D drives of the PC104), both for the original Greene Bomber M244 and the replacement unit sent out the day before. The entire HTI manufacturing department reportedly had worked on the problem and continued to do so in order to ship our system back to us Fedex overnight. We arranged for Cape Cargo to pick up the shipment in Boston (at Gareth’s house) and deliver it to the Provincetown harbormaster, who kindly agreed to deliver it to the ship Friday morning.

Delays associated with traffic, fog, and the railway bridge being down led us to clearing Cape Cod Canal around 1800, after which we headed for a spot half way to Provincetown in depths of ~40m for calibration of the HammarHead. Before deploying the HammarHead for calibration, we attached a metal bar to keep the tail at a fixed position relative to the towbail, in an effort to keep the fish horizontal. The fish was deployed with the usual monofilament rig (not the 30 lb test, but a slightly thinner one) with standard spheres of size 38.1mm and 21.2mm at ranges of ~8 and 6m, attached such that they would hang below the A1 transducer. The goal was to attempt a calibration relative to depth, since all of our previous calibrations have been in the WHOI seawell at a constant fish depth, but we tow the fish to depths of 200m. The transducers are intended to perform consistently to 500m depth, but this has not been tested. Winds were around 15-20 knots but the seas were very calm, making for quite nice calibration conditions.

The initial run did not go very well as the targets did not seem to make it into the center of the A1 beam, nor into the beam of any other transducer. The nose of the fish seemed a little too high and the roll was to port. We recovered the fish and removed the bar, in the hope that the fish would have more movement and that by pitching and rolling about it would once in a while get some good hits on the targets. At a depth of 5m this proved to be the case and Wu-Jung's quick analyses suggested we were getting good data. We therefore proceeded to do a series of calibrations at body depths of 5, 10, 20, and 25m, stopping again at some of these depths on the upwards trip. Analysis of the deeper data suggested the targets were not centered in the beam, likely because the motion of the fish was small at depth.

We therefore pulled the fish again, re-attached the bar but in such a way that the nose was angled down more than previously. This resulted in very good data and a series of runs at 5/10/20/10/5m. The bar was once again shifted to make the nose come down and even better data resulted. The final run involved positioning the targets under the MID/LOW/HH transducers which are on the starboard side of the towbody away from the A1, where they likely got fewer good hits on the earlier cal runs. Decent hits again seemed to be the case.

Friday October 29, 2010

The calibrations wrapped up around 0900, after which we headed for P-town to pick up the newly repaired HTI system. When we heard from shore support (Andone Lavery and Nancy Copley) that the shipment was delayed we did a test VPR cast in 30m of water. The altimeter did not function properly nor did the bottom switch. Worse yet though, after initial boot-up the system started (green LED) but wouldn't strobe and ultimately turned itself off. After the cast we found two files, one unreadable in Autodeck and one very short. A phone conversation from the unit's owner, Mark Baumgartner, led to the suggestion of doing a 'long boot' where the system is left idle for at least 5 minutes after it boots up before turning on the strobe. We did a series of tests with different hard-drive shuttles and different batteries of this long boot and things seemed to work fine.

After hearing that the shipment had arrived in Ptown around 1045 we headed into the harbor. Nancy had met the package at the harbor master's office, who came out in his patrol boat to make the drop-off. The transfer went very smoothly and we immediately started testing. Rub tests went well and so we put it in the water, and wet tests went fine too. We then spent an hour doing noise tests in order to make noise profiles for data collection. In the early afternoon everything was ready and we started out for Georges Bank.

Saturday October 30, 2010

With following seas we made up to 12 knots and reached Georges Bank around 0345. The Greene Bomber was deployed right away and the first mapping survey initiated. The HammarHead was left out of the water due to the seastate. The plan was to run 20nm long transects running perpendicular to the bank spaced 5nm apart. Each second line would involve VPR/CTD casts at stations about every 5nm. The first survey line was a non-VPR line to avoid having the boatswain up in the wee hours of the morning. Coming off the bank fish were evident near the bottom and then krill-like scattering as we got farther away from the bank. Unlike the previous cruise where the krill during daytime were in dense layers quite deep (160m+), in this case as day broke and through the morning the krill were quite shallow, around 100m or less. Below them however was a layer of fish-like scattering. Interestingly, on the second line the deep fish layer was absent and the krill were in a layer just off the bottom (ca. 200-215m).

The seas were building all day long and by the start of line 2 had reached ca. 7-11 feet. We decided to try a VPR/CTD cast nonetheless, which went quite smoothly in terms of logistics. The CTD also generated interesting profiles, with a sharp thermocline, a warm deep layer of slope water, and a bottom boundary layer below. The VPR performed poorly, however. After initially booting up and with a freshly charged battery, it again shut itself off. Removing and reseating the hard-drive got it to boot up and start strobing. It came back up after the cast still strobing, but with 4 sets of files, indicative of its having re-booted 3 times during the cast.

Before conducting the next cast, we swapped batteries and hard-drive shuttles, reformatted both drives, and changed out the battery cable for a cleaner one borrowed from Carin Ashjian. At the next VPR station it again shut down after the first bootup, but then strobed on the second boot. It was strobing upon recovery, but had 2 sets of files upon recovery. For the next cast we again swapped out batteries and battery case. Conditions were marginal and night was falling and so we decided against doing any further VPRs until the next day (or until the weather improved).

Despite the problems with the VPR, the acoustic mapping was extremely successful given the seastates and we are making very interesting observations. Tim White also had a full day on the flying bridge observing birds, including a number of gannets and dovekies.

Sunday October 31, 2010
Seastates remained fairly rough with windspeeds around 25 knots. The Greene Bomber and its tow boom continued to function perfectly and so multi-frequency surveying of the mapping grid continued. Due to the rough weather the HammarHead remained out of the water. The VPR initially continued to perform poorly, coming up with more than one file, with the files separated by long stretches of time (i.e., more than simply the reboot time of the VPR computer). Taking off the battery can after one such cast we found a small amount of water in the housing. The o-rings appeared fine which made us wonder about the bulkhead connector. A satellite phone call to Mark revealed that he had requested that Seascan replace the connectors this past summer, but that he had felt when they came back that only one looked like it had been replaced, so he wasn't surprised to hear that we suspected it was causing our problems. After swapping out the can for the backup the casts went much better. We continued to occasionally have problems booting the system, where it would take booting it twice for the strobe to come on, but it came back with only one file.

Tim White the bird observer was up on the flying bridge doing his survey right after dawn, and by 0900 conditions were good enough that the mammal observers went up as well and saw a humpback blow and a pod of pilot whales.

Monday November 1, 2010
The night watch wrapped up the first mapping survey around 0300. Looking at the HTI data the previous evening, we had identified a 5x5nm box with two sides running along transects 4 and 5 starting just off Georges Bank, around the 150m isobath. On both lines this region had large amounts of fish scattering, presumably herring, as well as krill-like scattering either co-located or above the fish, depending on time of day. Surveying of a 'bowtie' pattern inside this box started around 0500.

Occasional VPR casts were made to identify the animals present. The VPR worked well, although it continued to occasionally require two boots, and on one cast it came up with two files. Although conditions were marginal (20-25kn winds, 6-8' foot seas), because we had not yet managed any net tows, a MOCNESS cast was conducted shortly after lunch, capturing large amounts of krill in the deepest net. Interestingly, catches were quite small at mid-depths, where scattering was relatively high. We are suspecting that strongly scattering animals less readily identified by looking at sample jars, such as siphonophores or pteropods, may have been responsible for this scattering.

Conditions remained reasonable after sunset and so a night tow was conducted starting at around 2000, again catching reasonably high amounts of krill, now dispersed through the water column. Shallow depths (probably bounded by the mixed layer) were characterized by few sampled animals other than copepods that we think are Centropages, and very low scattering.

At 1800 I received an email from the chief scientist on the HB Bigelow, Heath, saying that they were nearby. Through a radio conversation and subsequent email exchange we learned that they had not been seeing krill in the stomachs of herring. Around 2100 we noticed them on our chart plotting software, doing a trawl that ultimately ran right through our survey box and along one of our bowtie transects. The following morning Heath emailed over to say that they had caught 95 herring in that tow and sampled the stomachs of three of those, all with empty stomachs.

Tuesday November 2, 2010

Surveying of the tracking survey bowtie continued through Tuesday night, in order to capture two sunrises and two sunsets. As for previous nights, during the wee hours we restricted operations to acoustic surveying only, completing at night-time MOCNESS or VPR work by midnight or earlier.

Although the winds remained at about 20kn, the seas had calmed down enough (6-8 foot) that the HammarHead was finally deployed shortly after 0700. When running the leg of the bowtie towards the SE the fish had to be recovered as the winds were out of the SW, which tended to push the ship onto the wire. For the other three legs of the survey though we were able to keep the HammarHead in and do towyos.

We were anxious to do a MOCNESS while in the bowtie (i.e., in the presence of lots of krill) with the HammarHead in the water, to do further testing of the strobe light system and collect co-located acoustic and net data. The strobe unfortunately did not work upon start up of the system. It's not clear what happened since MOC #2, but both the underwater unit 169 and the strobe did not operate. The tow was conducted anyhow in order to get the co-located data, although the krill catch was deflated due to the lack of strobe. A series of VPR casts were also conducted over the course of the day, with one cast again resulting in two files, but the rest functioning properly.

The MOCNESS tow was completed around 2300, after which time the ship headed to the second tracking survey bowtie location. This site was only ca. 2 miles away from the northern end of the first bowtie, but the mapping survey had suggested fewer herring, potentially making for an interesting comparison to bowtie #1. The HammarHead was pulled up for the night because Pat and Dave were going down so the night watch wouldn't be able to recover it.

Wednesday November 3, 2010

The forecast kept creeping on us, with good weather always a couple of days away. It finally arrived overnight, with seas down to 2-3 foot and winds less than 15 kn. Unfortunately the brake on winch #1 was broken and the HammarHead couldn't be deployed. By 1500 it still wasn't fixed, and we decided to do a daytime MOC tow even without it. The catch was very interesting, with the krill at their expected daytime depth close to the bottom, but then large numbers of pteropods in nets 5-6. Since we are doing a pteropod cruise next year and are interested in how to preserve them without damaging their shells, we pickled most of them but also froze some in the -70 freezer and preserved others in 91% isopropyl alcohol (since we didn't have ethanol).

The good weather also meant that the observers had a good day. Tim saw a number of bird species but at low abundance. The whale team of Reny and Kelly saw no animals. At least their zero observations were reliable though, unlike on some of the marine mammal surveying efforts from earlier in the cruise.

After sunset, around 2000, we had an opportunity to try some hand-lining. Although the probability of success seemed low and it was unclear whether any fish were on the sounder, the prospect of catching some herring to sample their stomachs was sufficiently attractive that we gave it a try. We jigged for 20 minutes, but caught nothing. Shortly before 2000, the engineers, with assistance from Dave, had fixed the winch and so after fishing the HammarHead was deployed. For this run we put Nick Woods' 1 MHz Nortek ADCP in a down-looking configuration, rather than the up-looking configuration we had used on the previous HammarHead run and all of the previous cruise's deployments. Meanwhile Dave and Peter were trouble-shooting the strobe, with wiring diagrams emailed from Al Bradley, supplemented by sat phone calls. The ultimate conclusion was that multiple components were likely bad, including most importantly the CPU in the strobe can. We therefore did the net tow, again without the strobe, but at least this time with the HammarHead. Following the tow, bowtie surveying with both the Greene Bomber and HammarHead proceeded through the wee hours of the morning.

Thursday November 4, 2010

The forecast was for 20-30 knots from the SE increasing to 30-40 during the night, with seas building to 13-20 foot. We therefore wrapped up the second bowtie around 0730, thereby capturing two sunrises and one sunset. Before ending the survey, we pulled the HammarHead in order to remove the Nortek ADCP. Since the previous evening we had been seeing strong interference on the A2 and A1 channels. This looked quite similar to interference we had seen previously that we thought was associated with dolphins and/or pilot whales. In this case though it was much more frequent and we were dubious it was from animal sources. We tried shutting off all of the other acoustic devices (the RDI ADCPs, the HTI 43 and 120) but the interference persisted. It also was only evident at larger ranges and did not move to closer range as we tow-yoed the fish, suggesting that it was associated with the body itself. Much as it seemed strange that a 1 MHz ADCP could interfere with the A1 (30-70 kHz) and A2 (80-120 kHz), the only other explanation was the Nortek. Once we removed the Nortek the interference went away on the A2, so perhaps it was some kind of sub-harmonic, or mechanical pressure waves? The lesser noise that was on the A1 persisted.

At 0800 after everyone had breakfast we pulled both towed fish and by 0830 were en route towards the west. Our initial destination was 42deg 20'N, 69deg 45'W, a location in western Wilkinson Basin which was where Chuck and Peter had done a krill SSL study in 1992. Winds were out of the SE and were building rapidly, as were seas. By 1700 we were mid-way through Wilkinson Basin and things were rough enough that the ship went hove-to. Conditions were not suitable at Chuck's site and so we continued on for Cape Cod Bay.

Friday November 5, 2010

Seastates in Cape Cod Bay were reasonable and so we decided to proceed with a calibration of the MOCNESS flowmeter. This involves running a measured mile in one direction, then back in the opposite direction. With the Greene Bomber in the water we attempted this calibration but it was a qualified success due to large amounts of fishing gear in the area and the Captain was very frustrated by our pulling up a couple of lobster pot buoys. Shortly after noon we deployed the HammarHead for further in situ calibrations. Seastate was sub-optimal though and after a few hours of calibrating we lost the targets, which we took as a sign that the cruise's science activities were finished. We therefore headed for the Cape Cod Canal and home.

Saturday November 6, 2010

We returned to the URI GSO dock around 0730. Most of the gear was already packed up (including a very thorough job of disassembling and lubing up the MOC) and ready for transport home. The large items were staged on the dock for when the WHOI truck would come later in the week and the electronics were loaded into a van. The science party members were thus soon on their way home.

Instrumentation, Methodologies, and Preliminary Results

6. Equipment Configuration

The Hammarhead towed body housing the Edgetech broadband system was deployed from the starboard side J-frame (Figure 6.1) via the Endeavor's oceanographic winch #1. Due to the wire getting oily during an earlier cruise to the Gulf of Mexico the EM 3-conductor cable on this winch had recently been shortened to 1477m. Tests conducted immediately prior to EN484 had confirmed that this short length of wire would provide the necessary bandwidth for the Edgetech system (tests done at WHOI previously had found that by ca. 2000m the bandwidth of standard UNOLS EM cable is compromised). During EN484 we had some issues with communication with the Edgetech unit seemingly due to a bad conducting wire and so on EN487 we changed to a different wire; dockside tests confirmed that the bandwidth using this other wire was sufficient. Both the VPR and MOCNESS were deployed via the stern A-frame using winch #2. Although the VPR is autonomous and does not require conducting cable, for this cruise we had borrowed Dr. Mark Baumgartner's VPR, which includes a full CTD. We therefore wired up this CTD through the winch in order to get real-time information on depth and altitude, and to use (or try to use) Mark's bottom switch. This required some initial fiddling with baudrate and sampling intervals, but communication worked fine. The MOCNESS communicated with the deck unit fine with the ca. 10,000m of wire on winch #2. Only one of these two winches can be operational at any given time and swapping between them requires an engineer, making it a somewhat time consuming process (ca. 15 minutes).

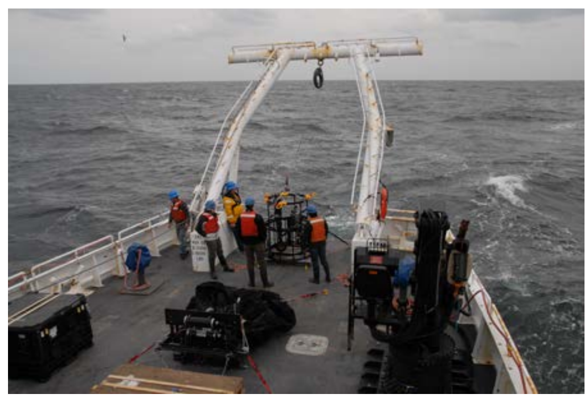


Figure 6.1. Main deck layout showing the deployment locations of the HammarHead (left) and MOCNESS/VPR-CTD (right). Photos: P. Wiebe.

The Greene Bomber was deployed over the port side using a new and very beefy tow boom designed by Terry Hammar in response to the issues we had with the pole borrowed from DSL during EN484 (Figure 6.2). This new boom, aka the Cannon, worked extremely well and the Bomber stayed in the water for the entire duration of the survey. Deployment was a labor-intensive process, with all four A/B's, multiple science party, and the bosun required. For deployment, the crane lifted the Bomber over the rail via a strap kept in place with a pin. Once in the water, tension was taken up on the towline and the pin was removed.

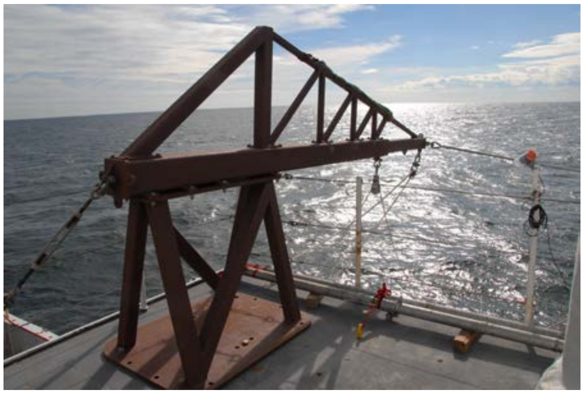
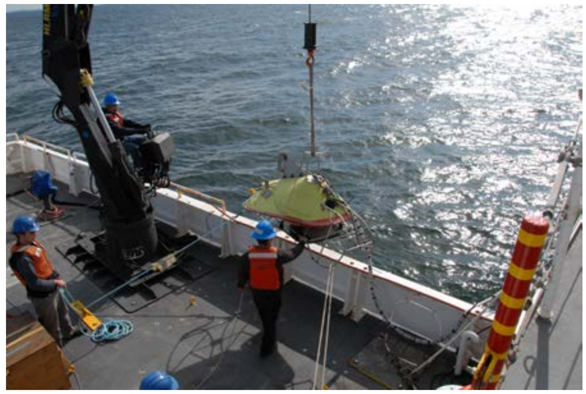



Figure 6.2 Greene Bomber tow assembly and deployment. Photos: P. Wiebe.

The main lab housed, in order of increasing distance from the stern on the athwartship benches (Figure 6.3):

- Against the aft wall a 'surgery' table for electronic repairs
- On the first bench a series of work stations occupied by the top predator observers and Nick Woods (ADCP processing), with the VPR processing computers opposite
- On the second bench, Gareth and Peter's work stations with the acoustic data collection computers opposite
- On the third bench, the event logger computer and Wu-Jung/Cindy's personal computers used for broadband data processing, with the MOCNESS data collection computer opposite.


Figure 6.3. Main lab layout (shown is from EN484, EN487 was the same). Photos: P. Wiebe.

The wet lab and its fume hood were used for MOCNESS sample processing. The small science lab forward of the wet lab was used by Nick Nidzieko during the night watch for his personal computer. Otherwise for the most part, personnel off-watch set up their laptops in the main lab.

7. Physical Oceanography

7.1. *Underway Sampling*

Along-track measurements were made continuously during the course of the cruise, to provide information on environmental conditions. Sea surface temperature, salinity, fluorescence and a variety of other data were collected upon leaving port. These data were saved on the ship's data server in several different file formats on a daily basis at 1-second, 1-minute, and 1-hour resolutions.

7.2. *CTD*

A Seabird-19plus CTD is incorporated into the VPR package borrowed for this cruise from Mark Baumgartner. All VPR casts thus also doubled as CTD profiles.

7.3. *ADCP*

Nicholas Woods

Although krill are relatively strong swimmers, ocean currents may play a role in determining the size, location, and density of krill patches. In order to understand the impact of ocean physics on these organisms, three Acoustic Doppler Current Profiler (ADCP) systems were used on this cruise: Shipboard 75 kHz and 300 kHz ADCPs and a Nortek 1MHz Aquadopp ADCP.

7.3.1. Shipboard 75 kHz ADCP

The Endeavor is equipped with a 75 kHz RDI Ocean Surveyor ADCP that was in use during the majority of the cruise. This instrument directly measured ocean velocity relative to the ship and acoustic backscatter at 75 kHz. Data were acquired using the UHDAS software, a suite of software designed at the University of Hawai'i. Preliminary processing on the raw data was also performed by UHDAS, and the processed data were stored in MATLAB files available on the shipboard data server. This preliminary processing includes rotating the velocities to Earth coordinates, ensemble averaging, and removal of the ship's velocity using GPS. The final product includes water velocity, ship velocity, backscatter amplitude, velocity error, and other diagnostic variables in 8-meter vertical bins and 5-minute ensemble averages, yielding a profile with a range of 22-814m every 5 minutes.

During the cruise, an external trigger often controlled the ADCP's ping emissions, so as not to interfere with other acoustic instruments. However, when the other acoustic instruments were turned off, the 75kHz was allowed to ping freely to maximize the amount of data collected. This cruise employed two different sampling schemes: cross-bathymetry sections ("transects"), and small-scale krill-patch surveys ("bowties"). Velocity and backscatter amplitude for an example transect are plotted in Figure 7.1. 3D velocity vectors for the same transect are plotted in figure 7.3 (top). The most predominant characteristic of the ADCP sections is the semidiurnal tidal flow (M2, ~12.42 hour period). The tidal velocities, in general, are strongest in the shallower water on Georges Bank, and weaker off the bank to the north. The sub-tidal flow may be particularly important in determining spatial characteristics of krill patches; however, due to the spatial variability of the tidal flow in this region, a simple method of removing the tidal velocity from the data is not readily available.

The data may be detided using a suitable tidal model, if one exists. If a suitable model cannot be found, the data may be de-tided as follows (from N. Nidzieko): Assuming that the along-bank variability in tidal current velocity and period is small, one may be able to create a time-series of current velocity and direction as a function of water depth (or distance from the center of Georges Bank). Then, using the T-Tide package from MATLAB, the component of the time series at tidal periods may be removed.

Problems: In shallow water, the ADCP does not perform well; the bottom mask provided by UHDAS does not recognize the bottom. The processing steps taken by UHDAS have not been verified on the ship; it may be wise to check these steps to be sure that they do not alias the data in any way.

7.3.2. Shipboard 300kHz ADCP

The R/V Endeavor is also equipped with a 300kHz ADCP, which was used periodically throughout the cruise, at times when possible interference with other acoustic systems was less of a concern (mostly during the short lines between transects). This instrument takes data in 60 2m bins with a surface blanking of 8m, yielding a profile with a range of 12-130m every 2 minutes. The data were processed using the same UHDAS method as the 75kHz ADCP (described above). An example of a transect of 300kHz ADCP data is plotted in figure 7.2, and a 3D vector plot is shown in figure 7.3 (bottom).

In shallower waters, this instrument may have interfered with the other acoustical instruments; during these times the 300kHz was either turned off, or switched to “narrowband” mode (which can be seen in the amplitude contour plot in figure 7.2). In “narrowband” mode, the standard error of the data was larger, but the interference with the other instruments went away. While performing mapping surveys, the 300kHz was turned on in “wideband” mode during the transect ends (e.g. figure 7.2 amplitude, ~0700-0830). These data will be especially useful in determining the spatial structure of the tidal currents, which will then be used to de-tide the ADCP data.

Problems: This instrument may have interfered with the multi-frequency acoustic data; during these times the ADCP was most likely turned off. There is no obvious evidence that the other acoustics interfered with the ADCP, but it may be a possibility. Also, this ADCP was not on an external trigger, so it did not run for the entire cruise. The data may be sparse in time and/or space, making de-tiding difficult.

7.3.3. Nortek 1 MHz Aquadopp Current Profiler

A Nortek 1 MHz ADCP was affixed to the top (and later, the bottom) of the HammarHead Towfish in order to measure current velocity and acoustic backscatter. The transmit frequency of this instrument was higher than that of the broadband acoustics on the Towfish, and it is a self-contained unit, requiring no communication while deployed.

The top-mounted ADCP was set to create a velocity profile every 10 seconds during deployment, as in EN 484. Each profile consisted of an average of 5 seconds of single-ping data. This resulted in an estimate of the single-profile velocity error of 5 cm/s. There were twenty vertical bins, each 1-meter in height, with a 0.41 m blanking distance between the instrument and the first bin. This deployment was used during the first deployment of the HammarHead.

A different set-up was used for the bottom-mounted deployment. The instrument took a velocity profile every second consisting of approximately 1 second of pings, meaning the instrument was continuously pinging. This setup yields an estimated velocity error of approximately 12 cm/s. We also increased the number of vertical bins to 30, effectively increasing the vertical range to 30m.

For each deployment the setup file was saved with a “.dep” extension. There was concern before deployment that the Nortek’s internal compass would be unreliable due to the strong magnetic field caused by the Towfish. Thus, the instrument logged data in “XYZ” coordinates, meaning that velocity is recorded relative to the instrument. The instrument’s coordinate system for the upward-looking deployment is depicted in Figure 7.4. The raw data will have to be rotated into Earth coordinates using a reliable compass heading (Towfish or shipboard compass).

The HammarHead was deployed and recovered a couple of times during the cruise. During longer periods on deck, Nortek data were downloaded using Aquapro software and backed up. This resulted in 2 different Nortek files (en487101.prf and en487201.prf). Each of these files was converted into ASCII data files (.a1, .a2, .a3, .v1, .v2, .v3, .hdr, and .sen), which are then read into MATLAB for later processing.

During deployment 1, the HammarHead was “towyo’d”, allowing the Towfish to fly to depth and back to the surface. At these times, more of the Nortek’s bins were underwater and there should be more useable data. However, the ADCP profiles were mostly out of the water, and strong backscatter amplitude was evident due to the surface (perhaps from bubbles). The movement of the Towfish through the water dominated the along-instrument velocity channel; this velocity was positive because the instrument is mounted facing backward (thus the water appears to be moving in the positive direction). The across-instrument velocity appeared to be negative for most of the time the fish was at the surface, which may be a result of the way the Towfish was flying through the water.

During the second deployment, the ADCP looked downward, and so all the bins were underwater the entire time the fish was deployed. Despite the fact that this deployment was much shorter (~12 hours), the sampling scheme yielded twice the amount of data, and nearly all of it was underwater, so may be useable. The effective range of the ADCP is approximately 25m, so the last 5 bins or so may be too noisy to use, but this will require further investigation. There also appears to have been some interference between the Nortek and the lower frequency channels on the HammarHead when the Nortek was mounted in this fashion.

Between the first and second deployments, the mounting brackets had developed cracks along the sides. The top plates were then removed and modified to act as mounting brackets for the bottom. Dave Nelson, the marine technician, supplied a third bracket made of metal strapping, which was used for the aft-most bracket.

Problems: The data were recorded in instrument coordinates because of interference between the Nortek compass and the innards of the Towfish. The velocity data need to be rotated to Earth coordinates using a reliable compass heading. Care must be taken to consider the fact that the Nortek was mounted facing backward on the fish. The velocity data are still contaminated with the Towfish’s velocity. This must be removed by some means (removing the ship’s velocity would be a good start). During the upward-looking deployment, the Towfish spent most of the time that it was in the water at the surface, meaning that the Nortek was not collecting useful data. The downward deployment yielded more useful data, but may have interfered with the broadband acoustics.

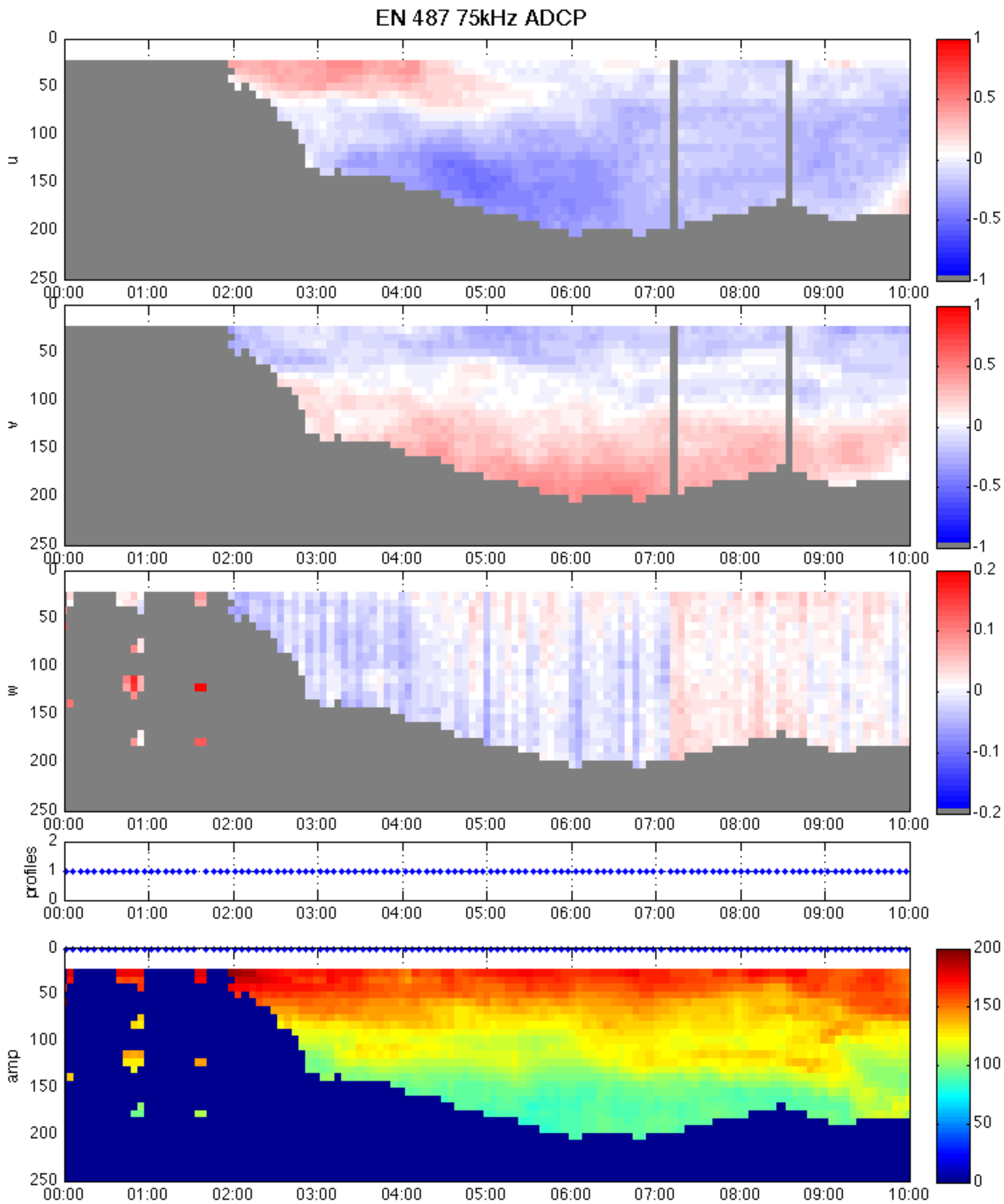


Figure 7.1. Shipboard 75kHz ADCP transect from 0:00:00 to 10:00:00, Oct 31, 2010. Eastward velocity (*first contour*), northward velocity (*second contour*), vertical velocity (*third contour*), and acoustic backscatter amplitude (*fourth contour*). Transect took approximately 10 hours to complete (times are in GMT).

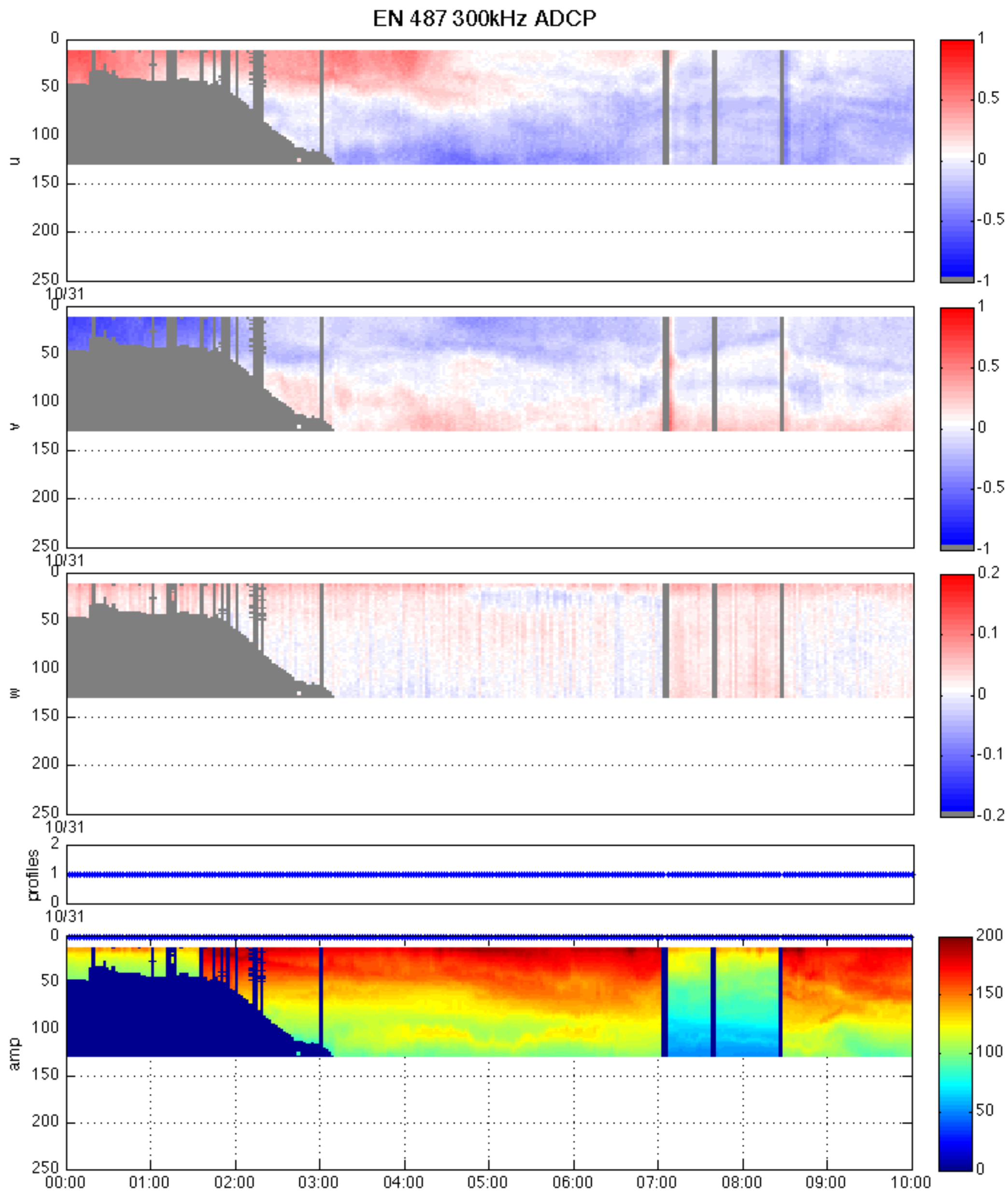
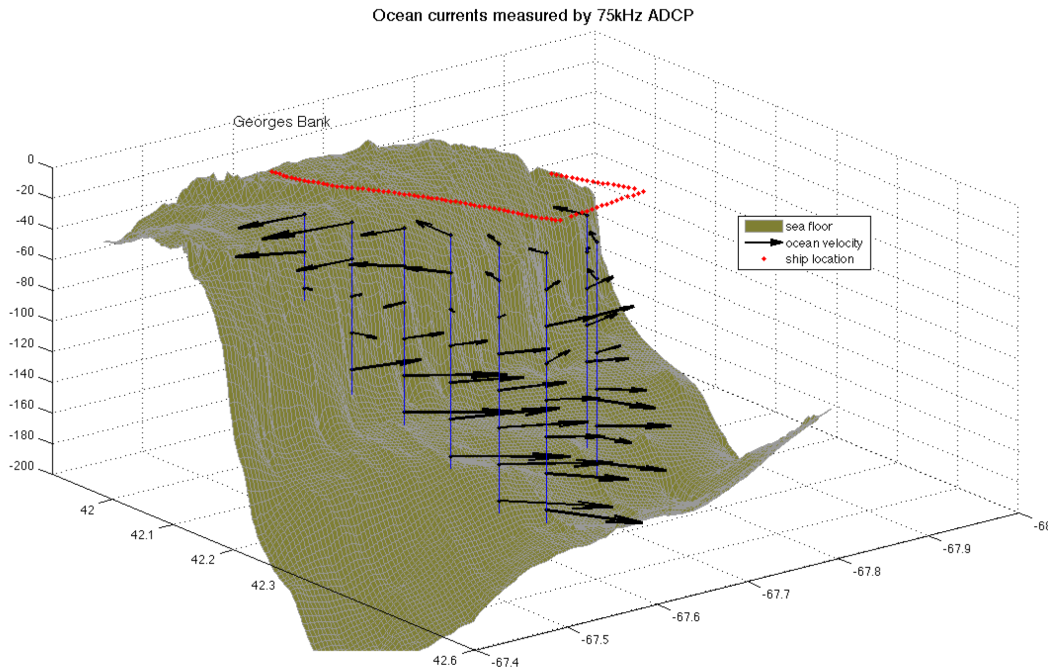


Figure 7.2. Shipboard 300kHz ADCP transect from 0:00:00 to 10:00:00, Oct 31, 2010 (same time period as figure 1). Eastward velocity (*first contour*), northward velocity (*second contour*), vertical velocity (*third contour*), and acoustic backscatter amplitude (*fourth contour*). Transect took approximately 10 hours to complete (times are in GMT). Period of lower amplitude in amplitude contour (from approx. 0700 to 0830) was the transect end, during which the ADCP was switched to wideband mode.



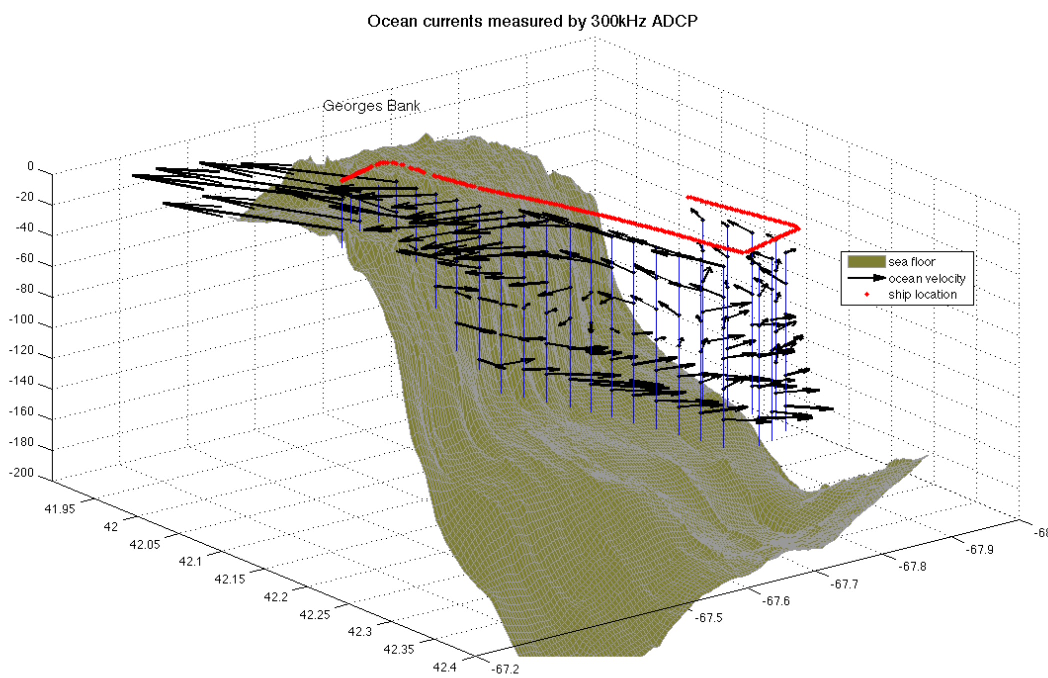


Figure 7.3. Shipboard 75kHz (*top*) and 300kHz (*bottom*) velocity profiles from 0:00:00 to 10:00:00, Oct 31, 2010 (same as figures 1 and 2). Every 10th profile is plotted in both figures. Every 3rd and 7th velocity vector is plotted for each profile for the 75kHz and 300kHz, respectively. The vertical spacing between vectors is 24m for the 75kHz, and 14m for the 300kHz. The vectors are scaled identically in each figure, and the longest vector plotted is ~1m/s.

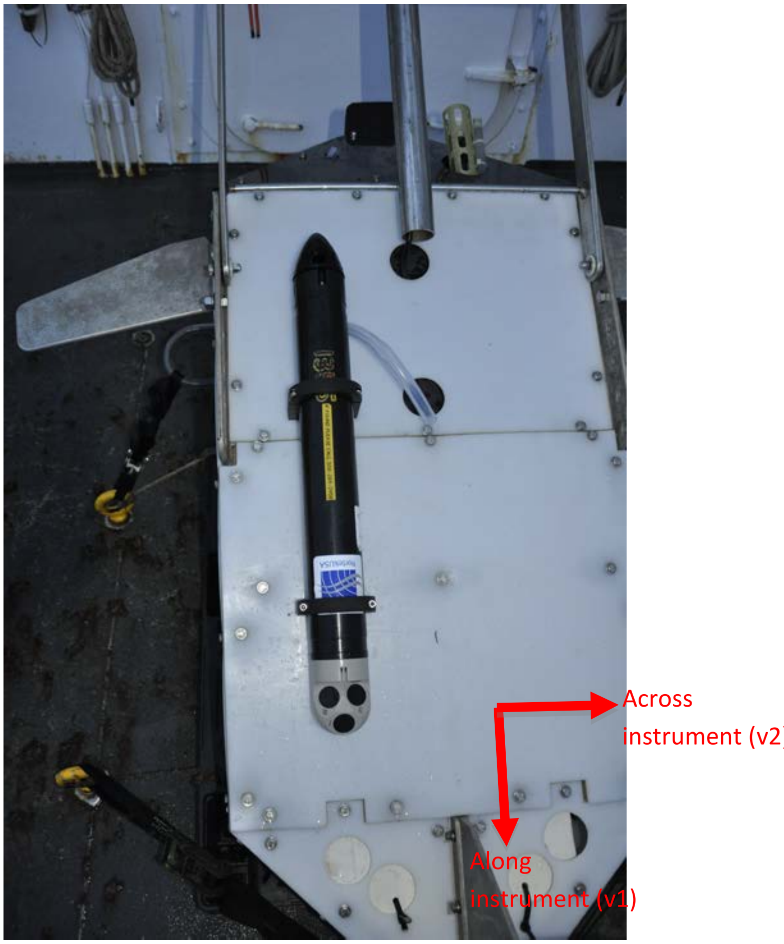


Figure 7.4. Nortek mounted upward-looking on the HammarHead. Arrows indicate instrument coordinate system. The z-coordinate (v3) is straight up (out of the page). The coordinate system is the same relative to the instrument for the downward-looking deployment. Photo: N. Woods.

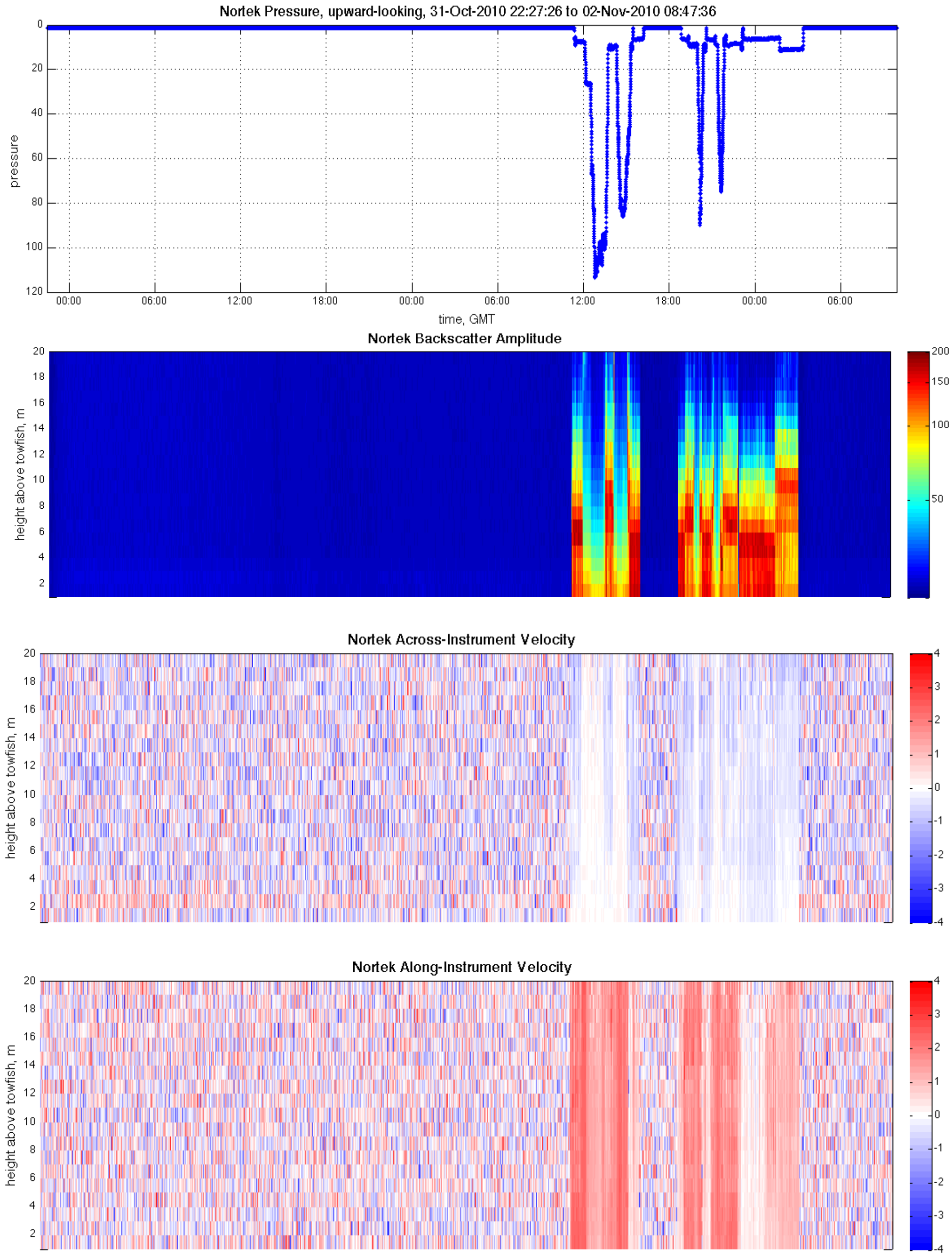


Figure 7.5. Nortek ADCP data during upward-looking deployment. Subpanels are, from top to bottom, pressure, backscatter amplitude, across-instrument velocity, and along-instrument velocity.

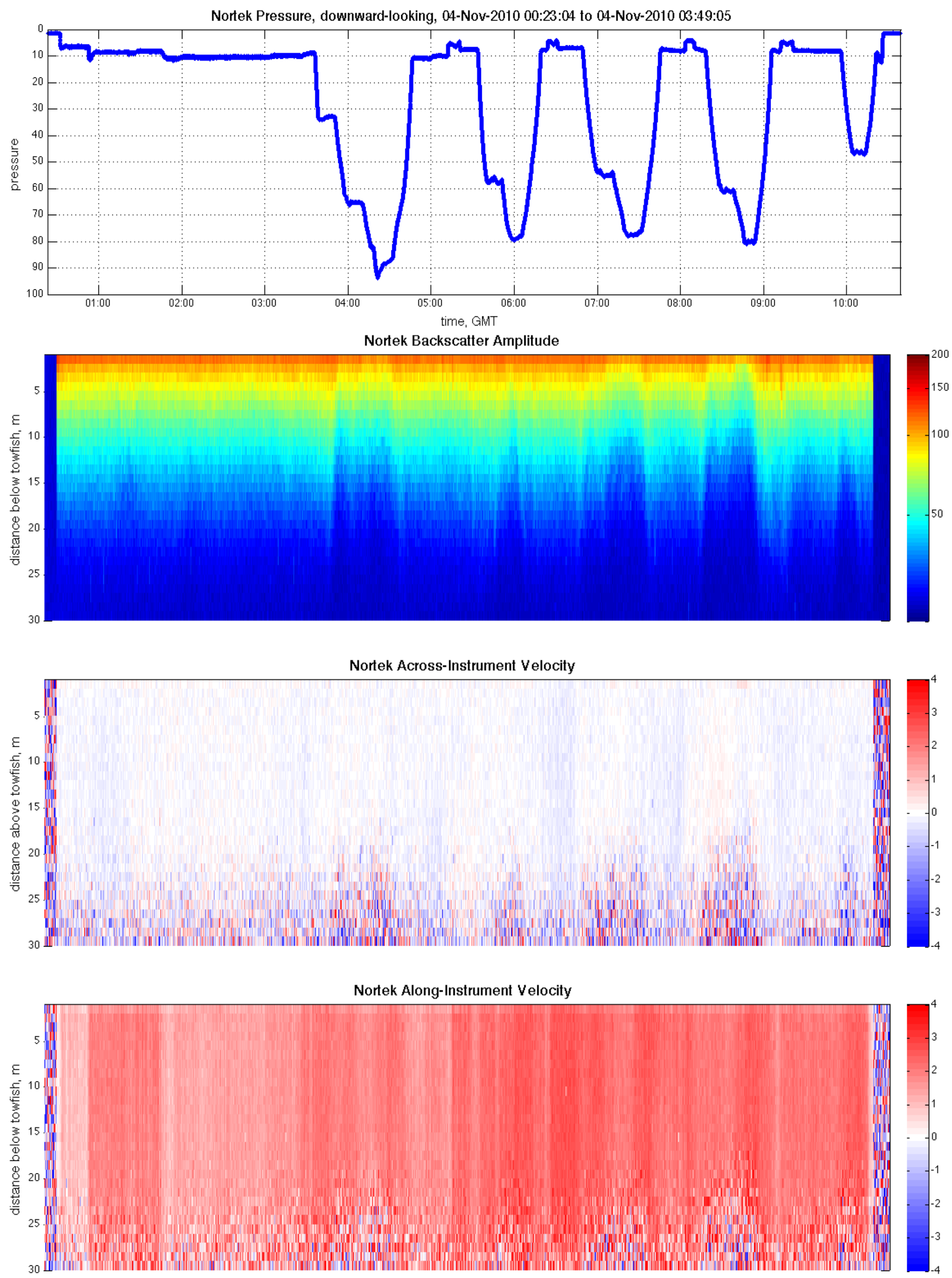


Figure 7.6. Nortek ADCP data during downward-looking deployment. Subpanels are, from top to bottom, pressure, backscatter amplitude, across-instrument velocity, and along-instrument velocity.

8. Zooplankton Sampling

8.1. *Multi-frequency acoustics*

Gareth Lawson

Quantifying the distribution of any marine organism requires sampling tools able to resolve adequately the scales of variability, which has led biological oceanographers in recent decades to employ a variety of increasingly sophisticated technologies. In particular, high-frequency active acoustic scattering techniques are uniquely suited to the study of zooplankton and fish distributions, as they provide remote and non-intrusive samples at high resolution and to large ranges, allowing patch structure to be quantified in fine detail: a task that is difficult to achieve using traditional net or optical sampling systems alone. Single frequency systems, while useful in this regard, are much less capable of providing insight into the composition of scatterer types present than is a system with multiple frequencies. Multi-frequency systems capitalize on the fact that different kinds of organisms scatter sound differently as the frequency changes, such that measurements of backscattering at multiple frequencies can be used to make inferences about the taxonomic composition of animals present.

On the current cruise, multi-frequency measurements were made near-continuously along-track and while on station during MOCNESS and VPR deployments. The goals were to collect acoustic data concurrent to sampling with other instruments in order to conduct cross-correlations; to characterize the distribution of scattering from biological sources, especially krill and fish, in relation to environmental conditions; to characterize patch structures as well as rates and amplitudes of diel vertical migrations; to provide indices of pelagic animal abundance to be correlated with other datasets, including observations of macrofauna.

8.1.1. Methods

High-frequency acoustic measurements were made using a Hydroacoustic Technology Inc (HTI) multi-frequency echosounder operating at frequencies of 43, 120, 200, and 420 kHz (Fig 6.3). One complement of four split-beam transducers at 43 (7 degree full-beamwidth), 120, 200, and 420 (all 3 degree beamwidths) kHz was installed in the Greene Bomber a 5' V-fin towed body, which was towed at a roughly constant tow depth of ca. 2-3m.

The HTI Model 244 Digital Echo Sounder (DES) deck unit (aka the big red box) was installed in the main lab, along with a Model 242 DES deck unit (aka the little red box) and the control laptop. The latter was used with a 24" flat-screen monitor to allow easy visualization of the real-time data. A GPS DB-9 feed connected to the laptop via a serial-to-USB converter provides GPS to the HTI Sounder.exe software. The M244 contained the transmit/receive cards and processed the raw data into integrated and target strength data streams, transferred to the control laptop over a local area network (LAN) and using Lantastic networking software. These are displayed and recorded by the HTI software and saved as hourly .INT (integrated data), .RAW (target strength), and .BOT (time and position) files. The raw data are also transferred from the M244 to M242 via a microphone cable, where they are processed and transferred via the LAN to the laptop to be saved as .SMP files. These 'sample' data allow us to later re-process the raw data using alternative noise profiles, depth strata, etc relative to what was used at-sea for the collection of integrated data, and can be used to look at the data on a ping-by-ping basis.

Acoustic data were collected nearly continuously over the course of the cruise during both transit and while on station, other than during brief periods of data transfer (mostly timed to occur during station activities), when the system needed to be shut down to avoid interference with the Edgetech broadband acoustic system, or when trouble-shooting some issue with the multi-frequency echosounder. Data were collected at vessel speeds of mostly 4 kn. Due to differences in absorption of acoustic energy by seawater, the range limits of the transducers are different. After testing various range settings and associated noise levels, the final configuration involved the 43, 120, 200, and 420 kHz channels looking to 300, 300, 150, and 100m, respectively, with corresponding interval durations to achieve these ranges of 650, 650, 350, and 250 ms. Integration intervals were set to 0.1 min and depth strata at all frequencies were set to 1m. When using the HTI system to trigger the Edgetech broadband echosounder (see next section), a fifth 'empty' period with an interval duration of ca. 1000 ms (the exact duration was experimented with over the course of the cruise) was used to provide the Edgetech sufficient time to complete its ping cycle.

The .INT and .BOT files were further post-processed by Gareth Lawson to convert the text files to Matlab format and concatenate the hourly files into daily sections. Echograms for these sections were generated and printed for groups of transects or bow-tie passes.

8.1.2. Problems and Solutions

Noise

The transducers operated very well with respect to noise. Initial noise tests were done in Cape Cod Bay during a series of test deployments. The HTI deck unit was plugged into the main lab's clean power supply, which resulted in good performance – during a previous Endeavor cruise the system had been plugged into the van's power strip which was receiving unclean deck power. That arrangement had led to strong noise at 120 kHz. The 420 kHz channel, like on the previous Endeavor cruise, was quite noisy but the other channels performed well, quieter than on the R/V Connecticut cruise conducted earlier this year. At the recommendation of the marine techs we did not use the UPS that we often use during dock tests because apparently the filters on the UPS interfere with the filters they use to clean up the power supply. Noise tests were done both with and without the HammarHead also pinging (synchronized). The noise profiles were pretty much indistinguishable, suggesting that the synchronization was working.

During surveying the acoustic data, especially at 43 kHz, were often subject to noise, especially as weather worsened, sea states increased, and tow body motion increased. Although the ship's speed was therefore often kept low the data quality was always useable.

Interference

A number of ship's acoustic systems interfered with the HTI frequencies, including the bridge sounder (ca. 50 kHz, interfering with the 43 kHz), ADCP (153 kHz, interfering with the 120 kHz), the Knudsen depth sounder (3.5 and 12 kHz, interfering with the 43 and 120 kHz), and the Doppler speed log (440 kHz, interfering with the 420 kHz). The bridge and marine tech were very accommodating in allowing us to run with these systems all kept off.

Computer Issues

Getting the full system communicating was often problematic. The boot-up sequence involves having the laptop on, turning on the M242, then turning on the M244, then restarting the M242. In some instances this process had to be repeated multiple times to get the M242 and M244 communicating and the samples data logging.

8.1.3. Preliminary Results

Multi-frequency acoustic data were collected for most of the cruise and over a reasonable geographical area. As had been the original proposed goal, by examining the frequency response of different scattering layers, coupled with strategic VPR deployments, we were able rapidly at the start of the cruise to identify krill layers (e.g., Figure 8.1.1). Following the initial mapping survey, particular regions were selected for tracking, where again on the basis of frequency response we were able to confirm that we were remaining with the krill aggregations. Qualitative examination of the data suggest that these krill aggregations are very large, extending farther both off- and along-bank than we were able to survey. Fish-like scattering was also clearly evident in the multi-frequency data, with aggregations of fish found immediately at the edge of Georges Bank and often a bit farther off-bank as the bottom dropped off further (e.g., Figure 8.1.1).

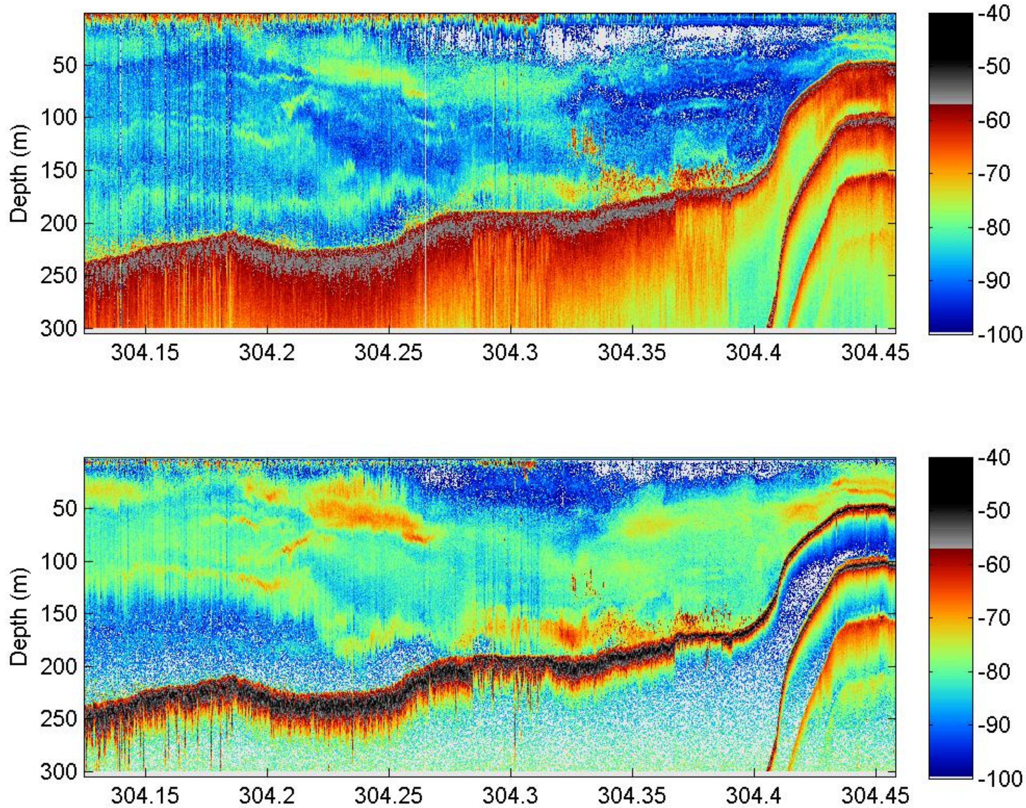


Figure 8.1.1. Acoustic data collected with the HTI system at 43 (upper panel) and 120 (lower panel) kHz along transect 4 of the mapping survey. Intense scattering likely associated with fish is evident near the 150m isobath adjacent to Georges Bank. Weaker scattering likely associated with krill is pervasive along the transect beyond the ca. 150m isobath. Note the downwards vertical migration of the krill-like scattering associated with dawn.

8.2. *Broadband acoustics*

Cindy Sellers, Wu-Jung Lee, Gareth Lawson

A chronic difficultly in the use of acoustics to quantify animal distributions lies in discriminating among the various animals likely to be present and contributing to acoustic scattering measurements. With only one or a limited number of frequencies, the problem of solving for quantities like the abundance of each animal type present is strongly complicated by differences in the scattering characteristics of the different types: at a single frequency, a given level of observed scattering could be accounted for by a large abundance of small and weakly-scattering organisms like copepods, or an orders-of-magnitude smaller number of strong scatterers like gas-bearing siphonophores. Broadband acoustic scattering techniques, of the sort under development by the co-PI A. Lavery for the past few years, offer the potential for substantial improvements in species discrimination due to the ability to measure scattering relative to frequency (i.e, the scattering spectrum, or acoustic signature) over a broad frequency range. In cases where a single taxon dominates scattering or in mixed assemblages where the scattering spectra of the different animals are sufficiently distinct, the sources of scattering can then be characterized and quantitative estimates of animal abundance and size made.

In earlier applications, a broadband system (ca. 150-600 kHz) has been used to identify and quantify thecosome pteropod abundance and size off the New Jersey continental shelf and verified relative to net samples. More recently, this system has been modified to include lower frequency channels (down to 40 kHz) in order to be able to quantify the Rayleigh to geometric transition for larger elongated scatterers like krill and used in krill applications such as the present project. One goal of this project is therefore a feasibility demonstration of the use of this modified system for remote identification of krill and other zooplankton, and for quantification of animal size and abundance. The broadband system is more range-limited than the multi-frequency system, and so the intention was also for the broadband system to provide improved species identification capabilities along its saw-tooth tow-yo trajectory, to supplement the multi-frequency system's more continuous measurements of water column scattering.

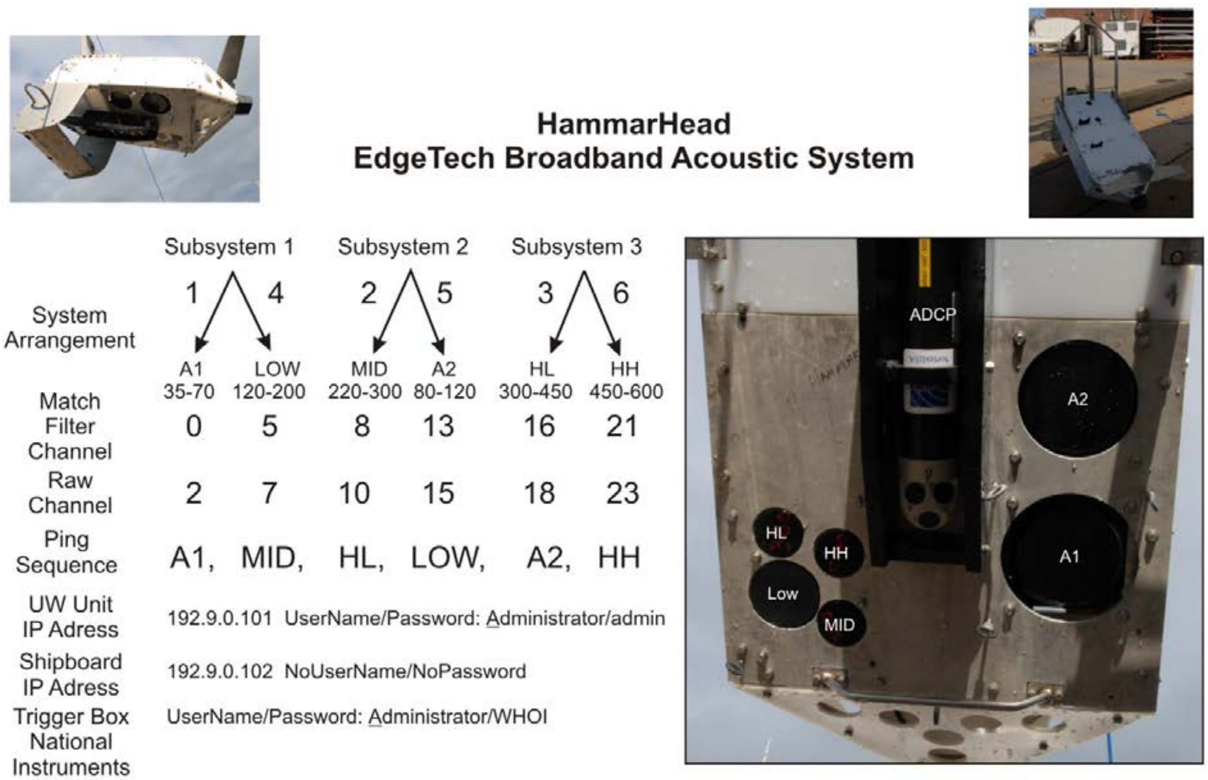


Figure 8.2.1 – Edgetech channel assignments and other settings [Photos: P. Wiebe]

8.2.1. Methods

A heavily-customized downwards-looking broadband acoustic scattering system manufactured by EdgeTech Marine and spanning a near-continuous frequency band of 40-600 kHz was used. This broadband system was limited to a maximum range of 50-150 m (varying with frequency) and so to achieve sampling over a greater depth range was towed obliquely up and down through the water column. The system operates at six channels, and the frequency bands and subsystem sharing for the six channels and associated transducers employed during this cruise are shown in Figure 8.2.1. These channel assignments reflect the channel assignments in the data acquisition software (JSTAR), however, the channel assignments in the data files are as follows:

These waveforms were used for the entire cruise:
A1L_10005_11005_5ms_00.spf
MA2_20005_12005_5ms_00.spf
H_30005_31005_5ms_00.spf

The high-low (HL) transducer failed and was not used on this cruise.

The broadband system was housed in a towed body nicknamed the HammarHead after its designer, Terry Hammar. Along with the broadband system and its 6 transducers was also a transponder, CTD, fluorometer, and pump (to provide sufficient water flow to the fluorometer). The top panel of the towed body is lined with corprene to baffle the transducers and prevent energy leaking out the back.

The HammarHead was deployed via the starboard J-frame using oceanographic winch #1. Two slip-lines were used in deployment. Snap hooks were used for recovery. One goal was to keep the HammarHead at the surface during MOCNESS/VPR deployments, to collect co-located data. This required tying off the tail of the towed body in order to prevent it from spinning around and/or hitting the side of the ship. To do so we brought the fish up to just above the surface, allowing a happy hooker to be used to put a line around one of the large U-bolts on the HammarHead's forward stabilizing foot. This line was then led aft and tied off. Once MOCNESS/VPR operations were complete and the ship underway the line was released and the HammarHead sent back to depth. Much of the time for maneuverability the HammarHead was kept at the surface. The exact depth of 'surface' tows varied over the course of the cruise but was generally ca. 10m. During tow-yos the rate of payout and haul-in as well as target depth were also varied adaptively, based on where the scattering features of interest were located and where the ship was located relative to turns. The winch had troubles maintaining a speed of less than ca. 15 m/min, however, and so this was generally our minimum speed. Because the towed body is quite light, getting it to large depths was time consuming.

The HammarHead topside electronics and data collection computer (named remote) were set up in the main lab running JSTAR. The yellow data cable (aka the deck cable) connected the deck unit (via an amphenol connector) to a screw-panel coming off the slip rings located behind the main lab's forward computer rack, via a short connector cable with spades on one end and a BNC on the other.

Data were collected to varying ranges on the two lower frequency subsystems (A1/Low and Mid/A2) and to 50m on HL/HH channel. The range for the lower sub-systems was mostly 75m but on this cruise we also explored greater ranges. This required turning off RAW data collection to keep data transfer rates within the available bandwidth. Ranges as large as 195 m were used successfully. The range was adjusted as needed to keep the bottom return out of the data return as JSTAR normalizes the received signals to the highest level in the received signal.

In general the following delays were used between channels (although see the comments below concerning the triggering system for more details):
A1/Low master
Mid/A2 delay 333
HL/HH delay 667

8.2.2. Synchronization of Acoustic Systems

Interference between the broadband and multi-frequency systems and the ADCP was avoided by synchronizing transmissions between the two systems using a National Instruments system and Labview program written by Wu-Jung Lee (a system overall referred to as Wu-Jung's box). The hope had been to send a trigger to each of the instruments in succession and the original Labview program implemented this plan. Problems in getting the HTI system to accept a trigger during EN484 led to an alternate arrangement and a second program where the HTI sent out a sync pulse and then was set to wait for some amount of time. Wu-Jung's box received this pulse, then sent out pulses to the Edgetech and ADCP.

8.2.3. Problems and Solutions

Deployment Strategy

The original plan had been for HammarHead deployments concurrent to all multi-frequency acoustic surveying. Because the J-frame can only extend a limited distance over the side, however, along many of our intended survey courses, due to wind direction the wire would tend towards the side of the ship. This made everyone nervous and also affected data quality. Deploying the HammarHead during MOCNESS operations was particularly tricky. HammarHead deployments were therefore much fewer than planned and because of worsened weather were even fewer than on EN484: only four deployments were achieved during the survey portion of the cruise.

Synchronization

Wu-Jung again spent a great deal of time over the course of the cruise trying to sort out the performance of the triggering arrangement because a number of problems emerged in getting the Edgetech system to behave as we wanted it to – it seemed to often miss pulses and change the order of channels in unexpected ways. These issues were not resolved during the cruise, but nonetheless, interference between the three acoustic systems did appear to be minimized.

Interference on A1 and A2 channels

When the HammarHead was shallow, we noticed short noise spikes on A1 and A2 channels. When the instrument was deeper, this noise disappeared. The source of the noise was not resolved. One speculation was that it was sidelobes from the hull. On occasion we saw trains of interference that Wu-Jung speculated might be dolphins, and at least once the appearance of such interference corresponded with dolphins nearby. Wu-Jung suggested we could quantify the click trains via the broadband data, which is a neat idea. On the one occasion where we installed the Nortek 1 MHz ADCP in down-looking mode we saw strong interference on the A1 and A2.

8.2.4. Preliminary Data

Calibrations

A series of calibrations were performed in Cape Cod Bay both before and after the survey portion of the cruise. The same calibration rig was used for both days but was lost at the end of the second day. With this setup the 21.2mm sphere was at 5.8m range, the 38mm sphere was at 7.6m range and the shackle was at 10.6m range. A rigid bar was attached to the HammarHead tail to hold the pitch steady. This bar was attached at the rear in different holes to try to get the spheres in the center of the main beam for each system. The forward end of the bar was attached in the first 2 holes on the tow bail.

Five different specific setups were used and are detailed in the table of data files below. Initially data were collected at 100% power but was reduced to 60% to match the well calibration done on 10/20/10. Data were collected initially to 15m range but this was changed to 11.5m when the bottom came into view as the HH was lowered deeper into the water column. In the table below, the power refers to the 4 lower channels. The HH channel was at 30% power. Files and folders were again named according to date and survey type:

Calibration Data:

10282010_cal/: file #'s	HH Depth	Bar position	Power	Spheres Under
Cal1_capecodbay_000 - 011	5.9m	1	100%	A1
Cal1_capecodbay_012 - 021	10.5m	1	100%	A1

Cal1_capecodbay_022 - 029	20m	1	100%	A1

Cal2_capecodbay_000 - 002	5m	Loose - not attached	100%	A1
Cal2_capecodbay_003 - 012	10m	Loose - not attached	100%	A1
Cal2_capecodbay_013 - 022	20m	Loose - not attached	100%	A1
Cal2_capecodbay_023	20m	Loose - not attached	60%	A1
Cal2_capecodbay_024 - 027	25m	Loose - not attached	60%	A1
Cal2_capecodbay_028 - 031	21m	Loose - not attached	60%	A1
Cal2_capecodbay_032 - 042	11.1m	Loose - not attached	60%	A1
Cal2_capecodbay_042 - 045	5m	Loose - not attached	60%	A1

Cal3_capecodbay_000 - 009	5.2m	2	60%	A1
Cal3_capecodbay_010 - 033	10m	2	60%	A1
Cal3_capecodbay_018 - 025	19.9m	2	60%	A1
Cal3_capecodbay_026 - 029	10.4m	2	60%	A1
Cal3_capecodbay_030 - 033	5.6m	2	60%	A1

Cal4_capecodbay_000 - 008	5.6m	3	60%	A1
Cal4_capecodbay_009 - 016	10.2m	3	60%	A1
Cal4_capecodbay_017 - 024	20m	3	60%	A1
Cal4_capecodbay_025 - 032	30m	3	60%	A1
Cal4_capecodbay_033 - 037	20m	3	60%	A1
Cal4_capecodbay_038 - 041	10.4m	3	60%	A1
Cal4_capecodbay_042 - 049	5.6m	3	60%	A1

Cal5_capecodbay_000 - 009	5.3m	3	60%	L/M/HH
Cal5_capecodbay_010 - 017	10.2m	3	60%	L/M/HH
Cal5_capecodbay_018 - 025	20m	3	60%	L/M/HH
Cal5_capecodbay_026 - 033	30m	3	60%	L/M/HH
Cal5_capecodbay_034 - 039	20.4m	3	60%	L/M/HH
Cal5_capecodbay_040 - 044	10.7m	3	60%	L/M/HH
Cal5_capecodbay_045 - 048	5.6m	3	60%	L/M/HH

Generally these data contain pings with echo amplitudes comparable or in some cases better than the data collected in the WHOI well on 10/20/10.

A second day of calibration was done at the end of the cruise and is summarized below. For this calibration we started pinging at 1Hz but at some point we changed the pinging rate to 2Hz. None of these data seem to be as high quality as those taken on 10/28/10. After the first calibration bout we moved the spheres to under L/M/HH and changed the bar back to position 2 but when the system was redeployed, the spheres were not in the echo...the monofilament broke.

11052010_cal/: file #'s	HH Depth	Bar position	Power	Spheres Under
Cal_capecodbay_10m_000 - 004	10m	3	60%	A2
Cal_capecodbay_20m_000 - 003	20m	3	60%	A2
Cal_capecodbay_30m_000 - 002	30m	3	60%	A2
Cal_capecodbay_10m_005 - 006	10m	3	60%	A2
Cal_capecodbay_5m_000 - 002	5m	3	60%	A2
Cal_capecodbay_5m_003 - 006	5m	4	60%	A2
Cal_capecodbay_20m_004	10m	4	60%	A2

Weather conditions prohibited the HammarHead from being deployed for most of the cruise. The system was deployed on 10/29/10 and triggering tests were performed. On 11/02/10 the HammarHead was deployed. More triggering tests were done and finally it was decided to turn off collection of the raw data to ensure all the data could come up the wire. Even so, once in a while a ping was lost.

Files and folders were named according to date and survey type, and are as follows:

11022010/:
HTI_trig_EAE_200ms_000 - 004 20101102 07:40L - 07:51L
HTI_trig_AEA_200ms_000 - 003 20101102 07:51L - 08:04L
HTI_trig_AEA_200ms_noRaw000 - 002 20101102 08:04L - 08:28L
internal_trig_wRaw_200ms_000 - 025 20101102 08:28L - 09:19L
HTI_trig_1pulsetoET_333ms_000 - 009 20101102 09:19L - 10:46L
The preceding were all trigger tests.

Next, survey data were collected with files of the form:
HTI_trig_1pulsetoET_333ms_noRaw_Xm_YYY
where X is the maximum range of data collected and varies from 80 to 185m.
See filelist_110210.txt (with the data) for a complete list of files in chronological order from this run.
Max range was changed as needed to avoid the bottom return.

11032010/:
HTI_trig_1pulsetoET_333ms_noRaw_000 - 086 20101103 20:53L - 20101104 08:06L
These files have data collected with varying ranges. Care was taken to avoid multiple depth ranges within a file, but the file name was not changed to preserve the chronological order more easily than for the files collected on 11/2/10.

Data Processing:
Raw data files (.jsf) were unpacked in Matlab via EdgeTechMicrostructure_smallGUI_2010_6ch_v1 that was altered at sea so that Lat/Lon information was extracted into the files properly. The altered routine was read_jsf_file_fun.m. *.mat files and *.png images were made for each channel for each data file, using the same file naming convention. Files from each data run were plotted together, one image for each channel, accounting for the depth of the towed body.

Overall the data appeared very encouraging. Visual scrutiny of the data during real-time collection and post-processing suggested multiple scattering features consistent with fish- and krill-like scatterers, similar to observations made with the multi-frequency system. A number of deep profiles positioned the towed body immediately above deep layers of putative different composition and it will be very interesting to examine these data in more detail.

8.3. *MOCNESS*

Kaylyn Becker, Peter Wiebe

8.3.1. Methods

A standard $1m^2$ Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) was used to collect zooplankton in order to determine the taxonomic composition of the zooplankton in the study region and also to ground truth acoustic data collected with the HTI multi-frequency and Edgetech broadband systems. The MOCNESS has 9 nets with a 335 µm mesh size that can sample different regions of the water column. The underwater unit used was #169.

In addition to the standard temperature and conductivity probes the system also had a beta-type strobe-light unit for reducing avoidance of the nets by some zooplankton, notably krill, and possibly small fish. The strobe system has two units each with 12 LED sets (LUXEON Rebel LED) with peak output between 490-520 nm. Two of the 24 LED sets were working inconsistently at the start of the sampling. The LEDs are powered by the MOCNESS battery and their pulse width, amplitude, flash rate period, and on/off are controlled by the MOCNESS software. For this cruise the pulse width was 40 ms, the relative amplitude was 99%, and the flash interval was 1000 ms.

The MOCNESS was launched and recovered from the stern A-frame. Samples were brought into the wet lab for processing. Nets 1-8 were preserved in buffered formalin. Often the net 0 samples were so large that they would have taken multiple jars so either the entirety or a large fraction was frozen in the -80C freezer, in the hopes that they might be useful. Some animals were also opportunistically sampled and preserved for genetic/genomic analyses (see below under opportunistic sampling).

8.3.2. Preliminary Results

Six tows were conducted over the course of the cruise, three during the day and three at night (Table 8.3.1; full details on these tows are in Appendix 1). The first five tows were conducted in the center of the survey region, at the location of the two tracking surveys (Figure 8.3.1). The sixth tow was conducted in Cape Cod Bay to calibrate the flow meter.

Table 8.3.1: MOCNESS tows carried out during EN487

Tow #	Date	Time Start	Time End	Latitude Start	Longitude Start	Latitude End	Longitude End
1	11/1/2010	1336	1446	42.0758	-67.7911	42.11675	-67.8060
2	11/1/2010	2016	2129	42.0622	-67.7827	42.0622	-67 .7827
3	11/2/2010	2149	2311	42.0622	-67.7827	42.0999	-67.8001
4	11/3/2010	1511	1636	42.2331	-67.8467	42.2037	67.7769
5	11/3/2010	2212	2303	42.1772	-67.828433	42.2187	67.8447
6 (cal)	11/5/2010	0917	1105	41.9780	-70.3284	42.1856	-70.3694

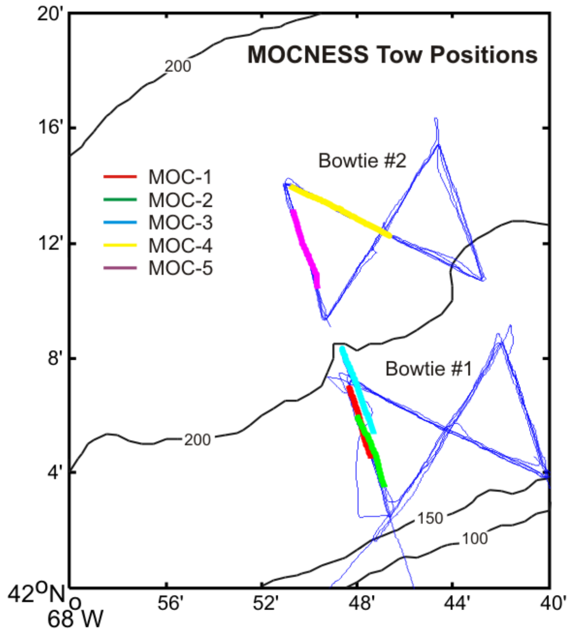


Figure 8.3.1 Positions of MOCNESS tows taken on EN487.

All tows were oblique and sampled the entire water column, except the calibration tow (#6). Tow 3 was an oblique tow with a horizontal segment in which a layer between 50 and 25 meters was repeatedly sampled with four of the eight nets, targeting a scattering layer of particular intereste. The first three tows were conducted on tracking grid one, the next two were on tracking grid two, and the final calibration tow was conducted in Cape Cod Bay. During the cruise the strobe lights on the MOCNESS failed, so only tow 1 and tow 2 had strobe lights operating. Based on the results of the strobe light experiment from the last cruise (EN484) and those from the first two tows on this cruise, the lack of the strobe light could have resulted in a dramatic underestimate the amount of krill in the water column in the final three tows. This is supported by tow three, which was carried out in the same area as tow two. Both were conducted at night in order to compare the differences between a night tow with a strobe and one without. A visual comparison of the two sets of samples indicated that there was substantially less krill in tow three (without the strobe) than in tow two (with the strobe). These results continue to support the hypothesis that that the strobe light over stimulates the krill's photoreceptors and prevent them from seeing the net and thus avoiding it. Even with the strobe light operating, it appears that there were less krill present on this cruise than on the previous one. We also noticed that there were many fewer salps and cnidarians than were present on the previous cruise. Pteropods were much more abundant than on the previous cruise, and were present at shallow depths.

The sixth tow's purpose was to calibrate the flow meter on the MOCNESS unit. The MOCNESS was towed at a depth of approximately 20 m for a distance of about one nautical mile from east to west and then in the reverse direction the same distance in order to eliminate any effect of differential current flow on the calibration. The calibration coefficient determined on this cruise of 6.425 m/count (Table 2) closely matches the coefficient determined in July 2010 while on a cruise aboard the R/V Connecticut of 6.397.

Table 8.3.2: Data used to compute the MOCNESS flowmeter calibration coefficient on EN487.

	Yearday-Time	Latitude	Longitude	Flow Counts	Tow Distance	meters per count
Start E=>W	309.3940	41.9813	-070.3353	112		
End E=>W	309.4195	41.9815	-070.3613	451		
			Total flow counts	339	2147.8 m	6.3357
Start W=>E	309.4361	41.9816	-070.3602	43		
End W=>E	309.4500	41.9816	-070.3449	237		
			Total flow counts	194	1263.8 m	6.5144
				avg. flow count		6.4251

8.4. *Video Plankton Recorder*

Philip Alatalo

A Digital Automatic Video Plankton Recorder (DAVPR) was employed to optically scan the water column for plankton and particles, providing information on the small-scale vertical distribution of smaller zooplankton and verifying acoustic inferences. The Video Plankton Recorder (VPR) is a system comprised of an underwater video camera(s), strobe, and environmental sensors designed by WHOI and Seascan, Inc. Several versions of the basic unit have been designed to sample from different platforms, in different manners. The DAVPR is a self-contained, digitally recording video microscope utilizing a Seabird Conductivity/Temperature/Depth sensor and a Wetlabs Fluorometer. The unit used on EN487 was borrowed from Dr. Mark Baumgartner of the WHOI Biology Department. The configuration of this system was somewhat different than the DAVPR used on the previous cruise, EN484. The optical package and the environmental sensors were deployed in a dedicated rosette cage.

The system collects images at a rate of 20 Hz, synchronized to a strobe light. Using 1 of 4 magnifications (named S0-S3), the video microscope can record plankton and particles, yielding information on the type and abundance of various sized particles in the water column. Targets for this cruise included krill, copepods, and salps. As such, the DAVPR was employed using its lowest magnification (i.e., S3 with a nominal view 4.2 cm x 4.2 cm). Because of the rosette cage arrangement, as in a typical CTD cast, undisturbed water was sampled only on the down-cast; the up-cast images were ignored.

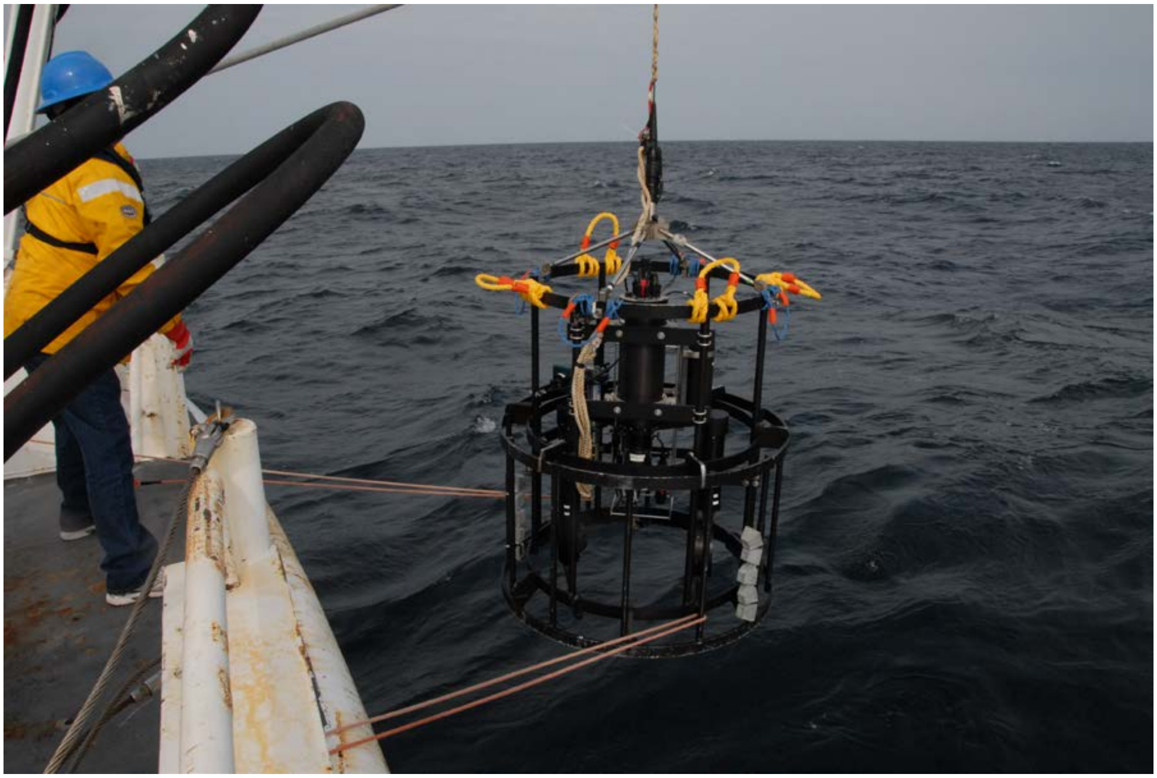


Figure 8.4.1. DAVPR launching from fantail of R/V Endeavor (Photo by P. Wiebe)

The VPR-CTD rosette was deployed via the stern A-frame and oceanographic winch #2, with the electrical termination attached to the CTD. Deployment involved slip-lines (Figure 8.4.1). Recovery required snap-hooks and a fend-off pole to keep the system from hitting the stern. Pat Quigley the bosun attached some extremely handy bails made out of thick polypropylene line to give us purchase points for snap-hooks. During deployments the ship kept a small amount of way on to keep the cage from going under the stern. After each cast, the detachable hard drive containing the cast video and CTD file was removed, downloaded to a computer, and scanned. Specialized software (Autodeck) allows extraction of in-focus images from the downloaded video file. This software was used between casts for initial extraction of data. After identifying the start and end frame of the down-cast, a dedicated user monitored the data extraction for the down-cast, noting the depths at which particular animals of interest (mostly krill and copepods) were observed. This information was used to guide the acoustic surveying and inform the choice of tracking survey location. Later analysis by Phil Alatalo in the lab will allow automatic identification, followed by manual confirmation, and abundance plots for each station.

8.4.1. Preliminary Results

In addition to a test deployment, the DAVPR was used at 19 stations (Table 8.4.1; Figure 8.4.2). Earlier casts were troubled by strobe problems, primarily premature shutdown at the start or multiple video files indicating that the strobe turned on and off more than once during a cast. Multiple files are typical when battery voltage is low, however voltage was fine. This led us to believe that the issue was power-related. By Station 6 we determined that a leaky bulkhead connector in one of the battery cases was the cause of our intermittent strobe failures. The following VPR casts used the other battery housing and were error-free.

EN487 VPR-CTD cast locations

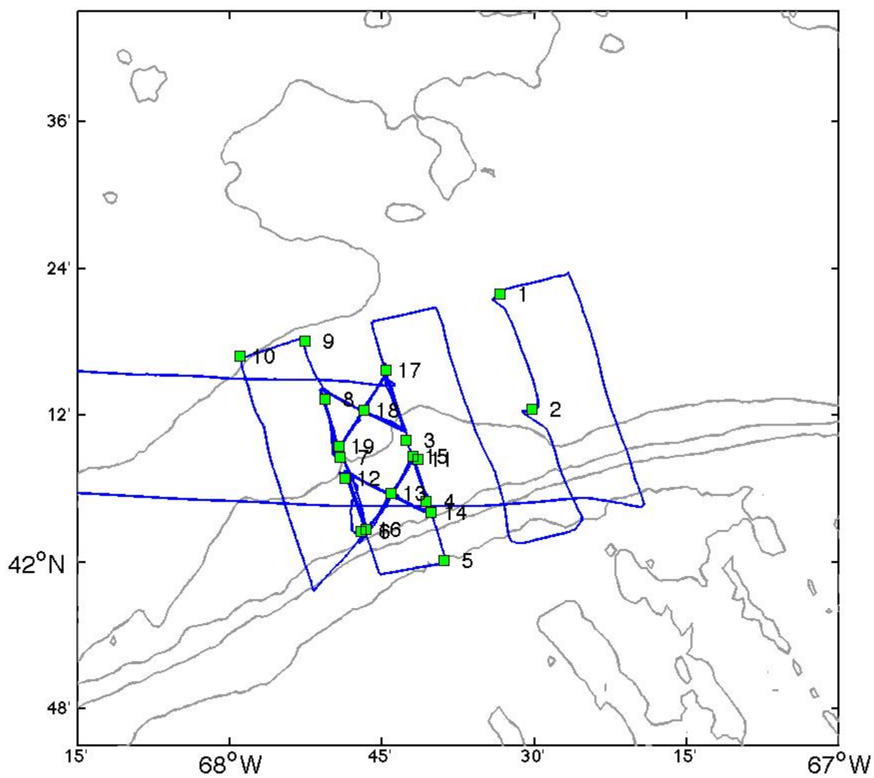


Figure 8.4.2. Location of VPR-CTD casts.

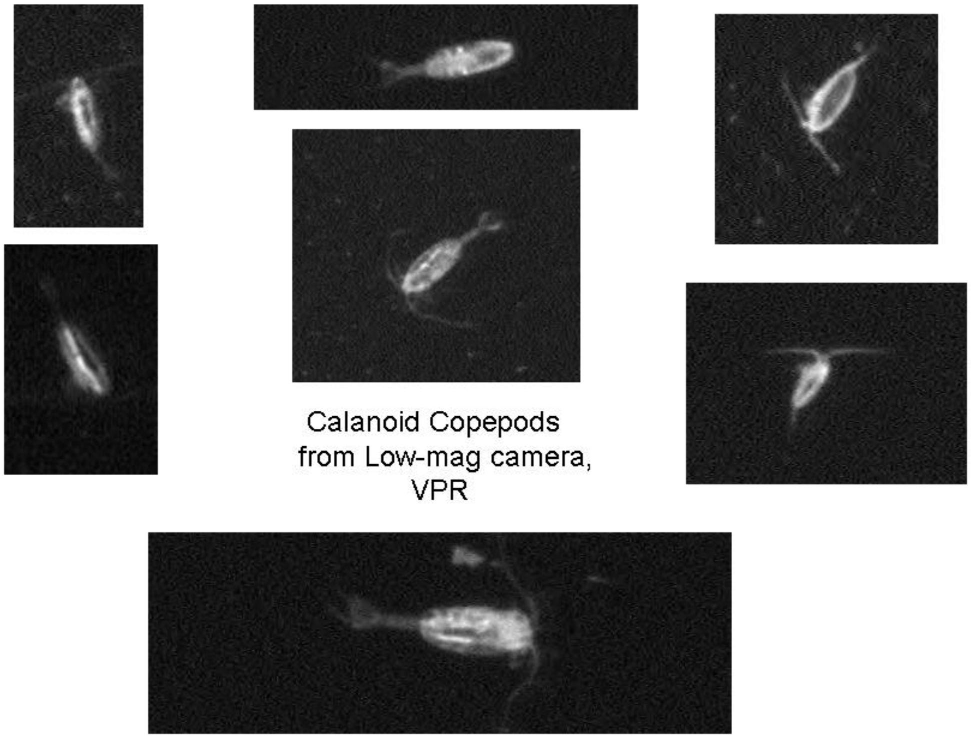
Table 8.4.1. VPR deployment data. Note that the YearDay convention used in VPR processing defines January 1 as YD 0, so the VPR year day is one day behind the year day convention used elsewhere for this cruise (e.g. in the HTI file naming, in the acoustic log). Note also that 'VPR number' is the number used in Phil Alatalo's later analyses and starts at 1 for the first survey deployment. This number is thus one less than the VPR cast number found in the event log, since there was an initial test cast (#1 in the event log) conducted in Cape Cod Bay. That test cast was at station #0, so the station number is equivalent to Phil's VPR number. Note also that Phil used VPR #20 to denote analysis of a second file associated with the cast at station 6.

Station	Date	Local Time	Phil VPR #	VPR Year Day	Local Hour
1	10/30/10	1046	1	302	10
2	10/30/10	1510	2	302	15
3	10/31/10	702	3	303	7
4	10/31/10	854	4	303	8
5	10/31/10	1039	5	303	10
6*	10/31/10	1313	6, 20	303	13
7	10/31/10	1526	7	303	15
8	10/31/10	1705	8	303	171
9	10/31/10	1905	9	303	19
10	10/31/10	2109	10	303	21
11	11/1/10	1000	11	304	10
12	11/2/10	1141	12	305	11

13	11/2/10	1331	13	305	13
14	11/2/10	1458	14	305	15
15	11/2/10	1645	15	305	16
16	11/2/10	1918	16	305	19
17	11/3/10	1017	17	306	10
18	11/3/10	1203	18	306	12
19	11/3/10	1331	19	306	13

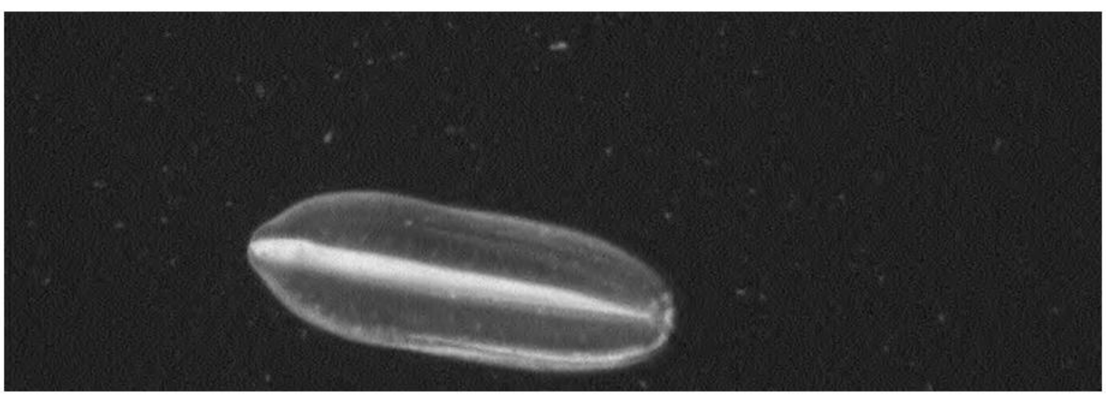
A variety of animals were successfully imaged with the VPR, including krill (e.g., Figure 8.4.3). As on EN484, the approach of doing 'quick' ground-truthing with the VPR so as not to interrupt the acoustic surveying was quite successful. Preliminary analysis shows that during the day, two populations of krill were often found at profile depths of 160m and at 200m or below. At night, migrating krill could be found around 45m depth. Copepods exhibited a more variable pattern. Quite often, they too, formed a deep layer between 150m and 200m. Daytime profiles showed copepods from the surface to 50m, sometimes extending in discrete layers to 150m. Usually copepods were evenly distributed except when concentrated in the deeper layers. On occasion they intermingled with the krill layer, but typically were separate. Large *Calanus finmarchicus* were common, as were smaller copepods representing either smaller stages of *C. finmarchicus* or smaller adult calanoids. In contrast to the previous cruise, salps were found once at the surface and once at 150m. Chaetognaths, ctenophores, and jellyfish were present, but relatively uncommon. Marine snow particles were generally rare except at a few stations where they were abundant, appearing to have been derived from a dwindling diatom chain population in the surface water. Long diatom chains, common during EN484, were far less abundant later in the season.

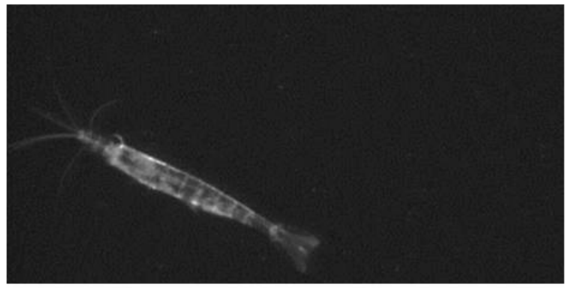
Figure 8.4.3. Example images collected with the VPR



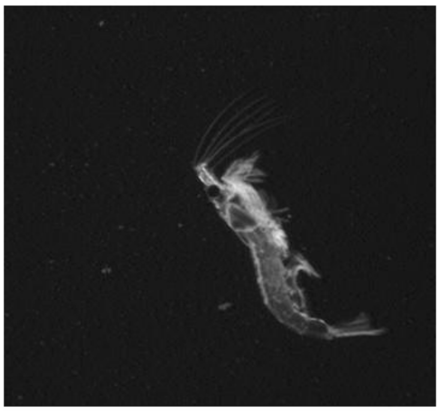
Calanoid Copepods from Low-mag camera, VPR

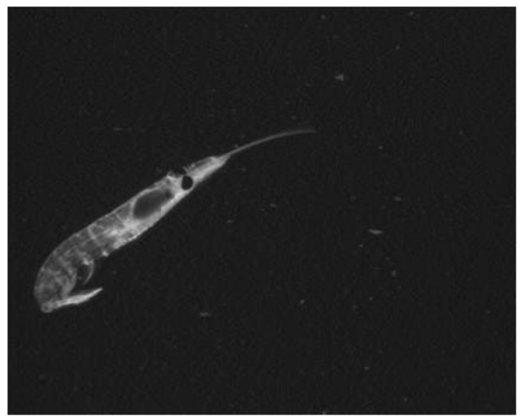
Ctenophore from low-mag camera, VPR





Krill from low-mag camera, VPR





9. Higher Predators

9.1. *Fish Sampling*

Gareth Lawson

The survey design for this project involves two cruises timed to occur before and after the herring spawn at which times they should be first not feeding and then feeding on their krill prey. Sampling herring to confirm their presence and determine whether or not krill were in their stomachs is difficult to achieve from a UNOLS vessel. At the recommendation of Mike Jech we purchased some handlines along with a series of hooked flies made to resemble krill. On one occasion, we attempted some hook and line fishing for herring, using these hand lines and some fishing rods Dave Nelson had along. Twenty minutes of fishing in this way was completely unsuccessful.

To provide additional information on the abundance and stomach contents of herring in the region, our cruise was done in coordination with Leg III of the NEFSC 2010 fall bottom trawl survey. We therefore remained in contact via email and radio with the FRV Bigelow for most of our cruise. As we had hoped, the Bigelow conducted some of its survey work immediately within our study region during our cruise. We will retrieve the results of those tows once they are available.

9.2. *Seabird Observations*

Timothy White

Visual surveys for seabirds and other surface-associated macrofauna (e.g., marine mammals, large pelagic fishes) were conducted as an unfunded add-on to the project. The goal will be to relate observations of these predators to concurrent measurements of the water column's biological environment.

Figure 9.2.1. Flying bridge macrofauna observation setup.

9.2.1. Survey Methods

A single observer (T. White) conducted visual surveys during daylight hours for the duration of the cruise, including the main study transect, but also during the transits to the survey start and from the survey end. The seabird observer, as well as the two marine mammal observers, were positioned on the flying bridge. The Endeavor's flying bridge had been outfitted for a previous marine mammal-focused cruise with a 'bimini top' as well as Bernoulli deflectors, making it overall a quite comfortable observing platform (Figure 9.2.1). Power and internet were supplied via a stuffing hole from the bridge.

Seabirds were identified to the species level and assigned a behavioral code. When possible, individual birds were assigned to an age class, as determined by plumage characteristics. Flight direction and association type, e.g, tuna, whales, fishing vessels, were also recorded throughout the survey; as well as observation conditions, such as visibility (scale from 0-5; 0= poor and 5=best) and Beaufort sea-state. In addition to seabirds, the observer recorded all other marine megafauna when encountered, e.g, tuna, marine mammals, turtles; as well as fishing vessels within 2 kilometers of the Endeavor. Distinguishable features, such as fronts or mats of macroalgae, were recorded in comment fields of the database.

Observations were recorded with the software Dlog 3 (Ford, R.G. 2010), continuously during daylight hours, while the ship was underway. Dlog 3 records location (decimal degrees) every few seconds, in GMT (ZULU) time; each observation was assigned a unique geographic coordinate and time stamp. Surveying was discontinued during stations and MOCNESS tows. In short, all birds were recorded within 300 meters of the ship, in a 90 degree arc from bow to beam, and from the side of the ship with the best visibility. Marine mammals were also recorded when encountered, and assigned an angle and distance estimate from the observer, in order to quantify detection probabilities.

The strip transect method (Tasker et al. 1984) was used for the majority of the survey period. All birds were recorded in a 300 meter strip width, from bow to beam (90 degree arc), on the side of the ship with the best visibility. The observer switched to the distance sampling method (Thomas et al. 2010) when seabird density was low, marine mammals were encountered, or when large groups of seabirds were beyond the strip width. Seabirds and marine mammals were counted only once upon entering the survey strip, and ignored if they followed the ship.

9.2.2. Preliminary Results

Seabird observations were initiated upon leaving Cape Cod Bay on 7 November. An impressive feeding aggregation of Northern Gannets (Morus bassanus) was observed around Race Point, Provincetown, MA; estimated number: 1,800 individuals. Large numbers of gannets are routinely observed during winter close to Race Point. It is possible that this large group prey upon on shoaling sand lance (Ammodytes americanus), which is common in the area, and also targeted by humpback whales (Megaptera novaeangliae). Groups of lingering common terns (Sterna hirundo), Bonaparte's gulls (Chroicocephalus Philadelphia), black-legged kittiwakes (Rissa tridactyla), herring gulls (Larus smithsonianus), great black-backed gulls (Larus marinus), and greater shearwaters (Puffinus gravis) were recorded as we exited Cape Cod Bay; as well as a fin whale and six humpback whales.

Northern Gannets, northern fulmars (Fulmarus glacialis), herring gulls and great black-backed gulls were abundant on Georges Bank. Herring gulls and greater shearwaters were observed feeding on fish in some areas, possibly Atlantic herring (Clupea harengus) or needle fish (Scomberesox saurus). Large numbers of gulls, greater shearwaters, and northern fulmars were observed feeding on offal from active commercial draggers, and a pod of long-finned pilot whales (Globicephala melas) was observed in close association with the fishing vessels.

The sea state was high during most of the survey and likely reduced detection of alcids. However, the sea state was low on 3 November, which improved observation conditions. Groups of dovekie (Alle alle) and Atlantic puffins (Globicephala melas) were observed in close proximity to each other, and also what appeared to be strong cross currents. Frontal zones can pool invertebrates and fish, potential prey for alcids. The MOCNESS was towed through the area and possibly sampled the alcid prey field. Observation conditions deteriorated on the return home, with winds blowing over 40 knots. Northern gannets, black-legged kittiwakes, northern fulmars, greater shearwaters, herring gulls, and greater black backed gulls were recorded on the steam back to Cape Cod Bay; as well as two small pods of dolphin—short-beaked common dolphin (Delphinus delphis) and white-sided dolphin (Lagenorhynchus obliquidens).

Also worthy of mention was substantial migratory "push" of land birds and water birds during the survey. Groups of common eider (Somateria mollissim), white-winged scoter (Melanitta fusca), long-tailed duck (clangula hyemalis), and common loon (Gavia immer) were all observed flying west or southwest over Georges Bank. Also, groups of common grackle (Quiscalus quiscula), goldfinch (Spinus tristis), snow bunting (Plectrophenax nivalis) dark-eyed junco (Junco hyemalis), American robin (Turdus migratorius), purple finch (Carpodacus purpureus) and a rusty blackbird (Euphagus carolinus) stopped to rest on the ship. Individual peregrine falcons (Falco peregrinus) were also observed migrating over the Bank.

9.2.3. References

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9.3. *Marine Mammal Observations*

Reny Tyson, Kelly Kleister

Visual surveys for marine mammals were conducted as an unfunded add-on to the project. The goal will be to relate observations of these top predators to concurrent measurements of the water column's biological environment.

9.3.1. Methods

Marine mammal observations were conducted concurrently with acoustic surveys from 27 October to 4 November 2010. Two trained observers (R. Tyson, K. Kleister) stationed on the flying bridge of the *R/V Endeavour* (observer height: 11.8 m) scanned for marine mammals using the naked eye and 7x 50 Fuginon binoculars with reticle marks in the oculars. Observers searched from directly ahead (0 degrees) to 90 degrees abeam of the ship. Observations occurred when the ship was underway traveling at a speed of 3-5 knots during reasonable sighting conditions (Beaufort sea state ≤ 4). Survey effort was often hindered by large swell or high Beaufort sea states and thus did not occur during all acoustic surveys or at night. Observers switched observation sides every 30 minutes and took breaks when needed.

Environmental conditions were recorded during each survey and updated every 30 minutes or more frequently when conditions changed. Swell height, swell direction, wind speed, wind direction, glare, Beaufort sea state, and weather conditions (% cloud cover, fog, rain, overcast) were recorded. When a sighting of a predator was made (marine mammal, large fish, sea turtle, shark) , the number of reticle marks from the horizon (used to estimate distance from the ship), bearing of the animal (estimated with a protractor), latitude, longitude, group size, cue (blow, splash, body) and species (when species could be determined) were recorded in the program *Logger* (IFAW). There were many instances when species could not be determined because the animal was seen too far from the ship, the environmental conditions were unfavorable, and/or we were unable to break transect to approach for better group size estimates or species identification. Overall environmental conditions were coded base on their suitability for effective observing (Table 9.3.1).

9.3.2. Results

Poor environmental conditions greatly hindered the amount of observations that were made during this study. From October 31 to November 4 2010 we surveyed for 10:12:45 hours and 77 km on effort and much of this was under marginal sighting conditions (BFT ≥ 5, swell height ≥ 2 m, winds ≥ 16 knots; Table 9.3.2, Fig 9.3.1.). Because of the poor sighting conditions many of our sightings can only be deemed as 'opportunistic' sightings; sightings should be thought of as being present at the time of their sighting (presence) and not as being present at the time of their sighting and not being present when no sightings were made (presence/absence). Sightings made on November 3, 2010, however, can be regarded as present/absent as the sighting conditions were extremely favorable (i.e., we can confidently say that there were few animals in the area).

We had a total of 3 on effort sightings including a humpback whale (*Megaptera novaengliae*), pilot whales (*Globicephala melas*), and a group of unidentified dolphins (Table 9.3.2, Fig 9.3.2). We had an additional 9 off effort sightings (Table 9.3.3) that were made when we were not actively surveying (e.g., poor environmental conditions, transiting, nighttime, etc.). Species sighted off effort included humpback whales, pilot whales, a fin whale (*Balaenoptera physalus*), common dolphins (*Delphinus delphis*), and white sided dolphins (*Lagenorhynchus acutus*). Sightings per unit effort were generally low for this study as few on effort sightings were made (Table 9.3.4). This may suggest that animals were foraging on the patch and we did not record their presence, animals were not foraging on the prey patch and we did not record their presence and/or animals were actively avoiding the area.

Table 9.3.1: Codes for survey conditions based on overall environmental conditions

Environmental conditions favorable for surveying
Environmental conditions okay for surveying
Environmental conditions marginal for surveying
Environmental conditions not good for surveying
Environmental conditions not appropriate for surveying

Table 9.3.2. Summary of effort status, environmental conditions and on effort marine mammal sightings

Date	GMT	Local	Lat	Long	Ship Speed	Search Status	Transect	Wind (knots) Speed	BFT	Swell Height (m)	Species	Group Size	Ship Heading	Distance (m)	Bearing from ship
31-Oct-10	14:05:28	10:05:28	42.03346	-67.65685	3.7	On Effort	4	16-20	4	1-1.5					
31-Oct-10	14:31:29	10:31:29	42.0073	-67.64725	2.5	Off Effort	4	16-20	4	1-1.5					
31-Oct-10	16:07:01	12:07:01	41.99082	-67.75709	3.8	On Effort	5	16-20	4	1.5-2					
31-Oct-10	16:41:42	12:41:42	42.02578	-67.77096	NA	On Effort	5	16-20	5	1.5-2					
31-Oct-10	16:57:43	12:57:43	42.04154	-67.77776	3.7	Off Effort	5	16-20	5	1.5-2					
31-Oct-10	17:53:21	13:53:21	42.0452	-67.79924	4.3	On Effort	5	16-20	5	1.5-2					
31-Oct-10	18:18:23	14:18:23	42.07463	-67.80032	NA	On Effort	5	16-20	5	1.5-2	Humpback Whale	1	5.7	704	-20
31-Oct-10	18:44:30	14:44:30	42.10466	-67.79099	NA	On Effort	5	16-20	5	1.5-2	Pilot Whale	4	332.9	50	35
31-Oct-10	18:57:26	14:57:26	42.11834	-67.80312	4.4	On Effort	5	> 20	5	1.5-2					
31-Oct-10	19:13:56	15:13:56	42.13762	-67.81281	4.5	Off Effort	5	> 20	5	1.5-2					
31-Oct-10	19:56:27	15:56:27	42.15269	-67.83138	3.9	On Effort	5	> 20	5	1.5-2					
31-Oct-10	20:00:27	16:00:27	42.15708	-67.83146	3.9	Off Effort	5	> 20	5	1.5-2					
01-Nov-10	12:49:30	8:49:30	42.0797	-67.67347	4.3	On Effort	9	> 20	5	2-3					
01-Nov-10	13:04:10	9:04:10	42.09552	-67.67838	NA	On Effort	9	> 20	6	2-3					

Date	GMT	Local	Lat	Long	Ship Speed	Search Status	Transect	Wind (knots) Speed	BFT	Swell Height (m)	Species	Group Size	Ship Heading	Distance (m)	Bearing from ship
01-Nov-10	13:14:48	9:14:48	42.10641	-67.68456	4.7	Off Effort	9	> 20	6	2-3					
02-Nov-10	19:47:54	15:47:54	42.10023	-67.68139	3.7	On Effort	25	> 20	4	1.5-2					
02-Nov-10	20:13:15	16:13:15	42.12376	-67.69144	3	On Effort	25	16-20	4	1.5-2					
02-Nov-10	20:21:55	16:21:55	42.13161	-67.69437	NA	On Effort	25	16-20	3	1.5-2					
02-Nov-10	20:31:43	16:31:43	42.14014	-67.6982	3.3	Off Effort	25	16-20	3	1.5-2					
03-Nov-10	11:29:20	7:29:20	42.22536	-67.82722	4.3	On Effort	33	11-15	1	0.5-1					
03-Nov-10	11:59:01	7:59:01	42.20728	-67.78476	4.5	On Effort	33	6-10	1	0.5-1					
03-Nov-10	12:28:42	8:28:42	42.18998	-67.74116	4	On Effort	33	6-10	1	0.5-1					
03-Nov-10	12:59:23	8:59:23	42.18557	-67.71521	3.6	On Effort	34	6-10	1	0-0.5					
03-Nov-10	13:30:23	9:30:23	42.22005	-67.73184	4.7	On Effort	34	6-10	1	0-0.5					
03-Nov-10	13:54:37	9:54:37	42.25038	-67.74414	NA	On Effort	34	6-10	1	0-0.5	Unidentified Dolphin	30	0.8	2817	-60
03-Nov-10	14:00:53	10:00:53	42.25701	-67.74373	3.3	On Effort	34	6-10	1	0-0.5					
03-Nov-10	14:05:20	10:05:20	42.25974	-67.7438	1.2	Off Effort	34	6-10	1	0-0.5					
03-Nov-10	14:52:53	10:52:53	42.26624	-67.74514	4	On Effort	35	6-10	1	0-0.5					

Date	GMT	Local	Lat	Long	Ship Speed	Search Status	Transect	Wind (knots) Speed	BFT	Swell Height (m)	Species	Group Size	Ship Heading	Distance (m)	Bearing from ship
03-Nov-10	15:29:43	11:29:43	42.22572	-67.76756	NA	On Effort	35	1-5	1	0-0.5					
03-Nov-10	15:36:46	11:36:46	42.21833	-67.77235	3.3	Off Effort	35	1-5	1	0-0.5					
03-Nov-10	16:39:18	12:39:18	42.19941	-67.78893	4.3	On Effort	35	1-5	1	0-0.5					
03-Nov-10	17:02:48	13:02:48	42.17811	-67.80436	3.3	On Effort	35	1-5	1	0-0.5					
03-Nov-10	17:24:39	13:24:39	42.15907	-67.81863	3.8	Off Effort	35	1-5	1	0-0.5					
03-Nov-10	18:00:06	14:00:06	42.17035	-67.82664	4	On Effort	36	1-5	1	0-0.5					
03-Nov-10	18:47:10	14:47:10	42.22276	-67.84763	NA	On Effort	36	1-5	0	0-0.5					
03-Nov-10	18:58:02	14:58:02	42.23419	-67.85142	3.5	Off Effort	36	1-5	0	0-0.5					
03-Nov-10	20:49:15	16:49:15	42.19853	-67.76491	3.9	On Effort	37	1-5	0	0-0.5					
03-Nov-10	21:22:56	17:22:56	42.18066	-67.71941	3.8	Off Effort	37	1-5	0	0-0.5					
04-Nov-10	11:16:48	7:16:48	42.19587	-67.72	4.2	On Effort	46	16-20	2	0-0.5					
04-Nov-10	11:20:42	7:20:42	42.20043	-67.72163	NA	On Effort	46	16-20	3	0-0.5					
04-Nov-10	11:32:30	7:32:30	42.21388	-67.72662	NA	On Effort	46	16-20	4	0-0.5					
04-Nov-10	12:02:20	8:02:20	42.24581	-67.73669	3.9	Off Effort	46	16-20	4	0-0.5					

Table 9.3.3. Summary of *off effort* predator sightings from 29 October to 04 November 2010. Often all associated data was not recorded for off effort sightings.

Date	GMT	Local	Latitude	Longitude	Species	Group Size Estimate	Ship Heading	Distance (m)	Bearing From Ship
29-Oct-10	NA	NA	NA	NA	Fin Whale	1	NA	NA	NA
29-Oct-10	~19:50	~15:50	NA	NA	Humpback Whale	2	NA	NA	NA
29-Oct-10	~21:30	~17:30	NA	NA	Humpback Whale	2	NA	NA	NA
29-Oct-10	~21:00	~17:30	NA	NA	Humpback Whale	1	NA	NA	NA
02-Nov-10	~1:00	~21:00	NA	NA	Common Dolphin	6	NA	NA	NA
03-Nov-10	~24:30	~20:30	NA	NA	Common Dolphin	1	NA	NA	NA
04-Nov-10	13:59:49	9:59:49	42.25605	-68.1256	Common Dolphin	5	270.7	10	0
04-Nov-10	~18:37	~2:37	42 18.649	69 11.291	Pilot Whale	NA	NA	NA	NA
04-Nov-10	~19:16:10	~3:16	42 19.036	69 19.489	White sided Dolphin	NA	NA	NA	NA

Table 9.4.4. Summary of effort, sightings, sightings per unit effort and transect ID

Date (2010)	Distance Traveled On Effort (km)	Time On Effort (hrs)	Number of on effort Marine Mammal Sightings	Sightings per unit effort (Sightings/km)	Transect ID's surveyed
October 31	20.3	2:41:17	2	0.099	4,5
November 1	3.2	0:25:21	0	0	9
November 2	4.7	0:43:46	0	0	25
November 3	43.1	5:36:53	1	0.023	33,34,35,36,37
November 4	5.7	0:45:28	0	0	46
Total	77	10:12:45	3		

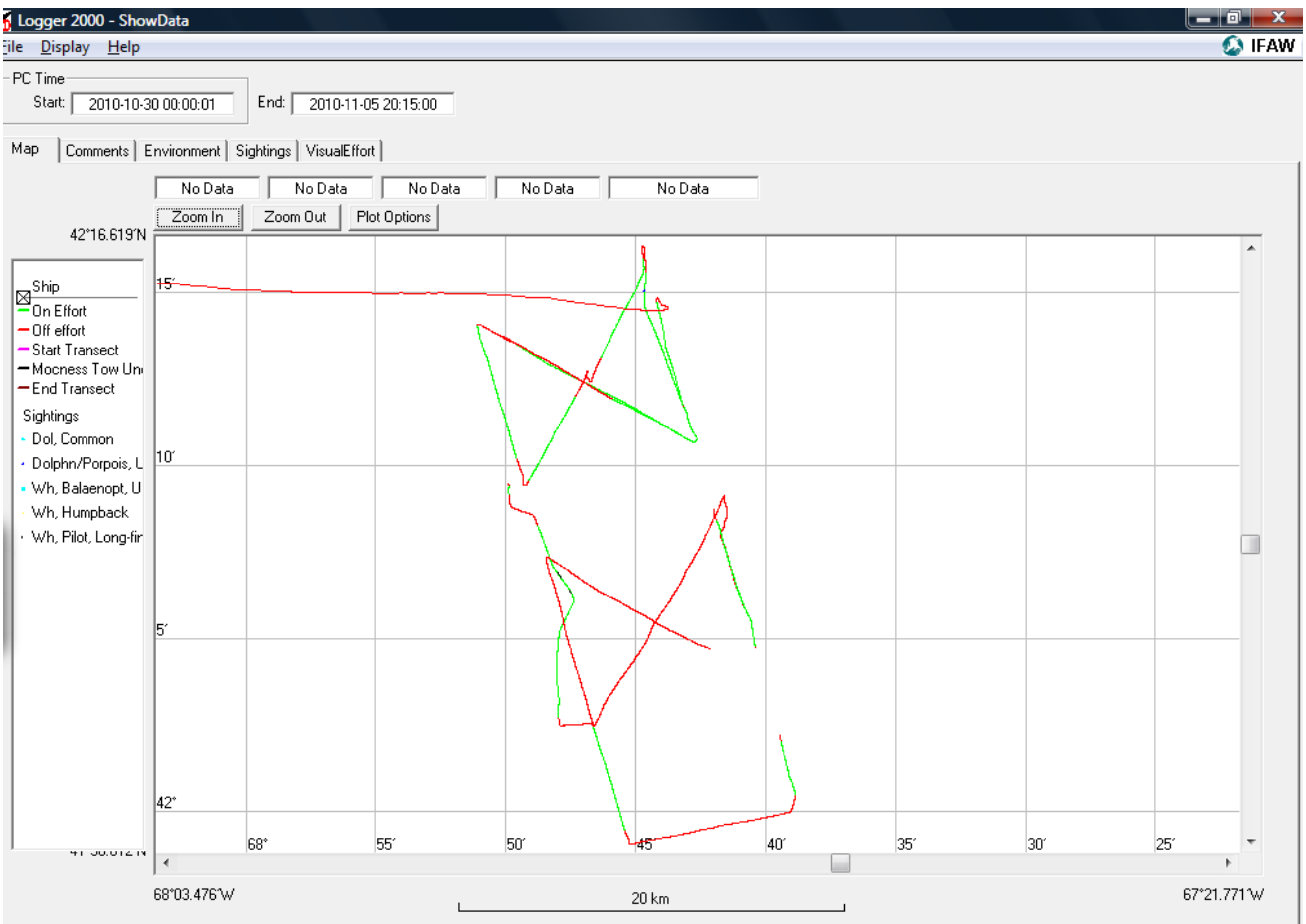

Figure 9.3.1. Map of effort and sightings created in the IFAW program *Logger*. Green lines represent on effort surveying and dots represent the ship location when marine predators were sighted.

Figure 9.3.2. Some of the marine mammal species identified during the surveys. (A) Common dolphin (*Delphinus delphis*); (B) long-finned pilot whale (*Globicephala melas*); (C1, C2) humpback whale (*Megaptera novaengliae*).

10. Opportunistic Sampling

10.1. *Collection, dissection, preservation/freezing of specimens for genetics/genomics.*

Peter H. Wiebe and Philip Alatalo

Studies are underway at the University of Connecticut to determine the genomics of some key marine zooplankton species. Target species are *Calanus finmarchicus*, a broadly distributed and dominate copepod in the North Atlantic temperate and Arctic boreal waters, *Meganyctiphanes norvegica*, a euphausiid that has a distribution range similar to that of C. finmarchicus, and the temperate salp species, *Salpa aspera*, although other salps and doliolids are also of interest. On this cruise, we were equipped to sort and preserve individuals of the target species while still alive that were collected in the MOCNESS tows.

Table 10.1 summarizes the sampling effort. On the first tow we took *Calanus finmarchicu*s from a lower net in the overwintering stock and a few from the surface sample (there may be some *Calanus* in the sample) and put them in small plastic vials with RNAlater. We also sorted 10 *Meganyctiphanes norvegica* out and put them in separate cryovials. They were put into a pantyhose and deposited in the liquid nitrogen.

For the second tow, which hit the bottom on net zero (just barely), there was a lot of mud and we did our best to preserve most of it by freezing it at -80C, but some of the sample was sieved and preserved in formalin (sorry about that). Several dozen *Calanus* from a deep sample were put into cryovials with RNAlater and refrigerated.

For the third tow, we again put a number of *Calanus* from a deep sample into two vials with RNAlater and refrigerated them. We also sorted 15 krill, put them in cryovials, and froze them in liquid nitrogen.

For tows four and five, we caught salps (probably *Thalia democratica*) in the upper 50 meters and after dissecting out the gut put the individuals in separate vials for freezing in liquid nitrogen. Ten individuals were frozen from MOC-4 and 20 from MOC-5. Also on each tow, several dozen *Calanus* collected in the deepest sampling net were placed in a pair of vials with RNAlater and refrigerated. In addition, ten large *M. norvegica* were individually frozen in liquid nitrogen from MOC-4 and MOC-5.

After 24 hours of refrigeration, the vials of *Calanus* in RNAlater were stored in a -20C freezer.

These collections will be taken for analysis by Paola G. Batta-Lona and Ann Bucklin at the University of Connecticut

Table 10.1. Animals collected for genetics/genomics research at UCONN.

Taxa	MOC-1	MOC-2	MOC-3	MOC-4	MOC-5
Calanus (RNAlater)	2 vials (1 deep, 1 shallow)	2 vials (deep)	2 vials (deep)	2 vials (deep)	2 vials (deep)
M. norvegica (liquid nitrogen)	10 individuals	None	15 individuals	10 individuals	20 individuals
Salps (*Thalia democratica*? (liquid nitrogen)	None	None	None	10 individuals	20 individuals

11. R2R Event Logger

Gareth Lawson

A detailed event log is an important part of every oceanographic cruise. Not only can it be used during the cruise to keep track of casts, equipment and to diagnose problems, but it also aids in data management after the cruise has ended. In preparation for the cruise we also discussed best practices for data collection with staff from the WHOI-based Biological and Chemical Oceanography Data Management Office (BCO-DMO), in anticipation of our archiving cruise data with that office and in accordance with NSF's policies on data management. BCO-DMO best practices include the use of an event log to record all scientific sampling events occurring during a cruise.

Traditionally, event logs begin in hand-written form and are transcribed to electronic form (such as an Excel spreadsheet). On this cruise, we tested a system that is electronic to begin with, so the hand-writing and transcription step is not necessary. This not only saves time, but increases accuracy as it eliminates several chances for human error. The software that was used on this cruise is known as "Elog", which is an open source event logging package that was configured to work with the Endeavor's data streams. A dedicated netbook acted as a server that allowed any computer on the ship's network to log events, including computers used by the macrofauna observers on the flying bridge (connected via a long Ethernet cable from the bridge).

Unlike on EN484 where we had a dedicated science party member (T. Work) who had the ability to modify the Elog parameters and was also tasked with cleaning up erroneous entries each night, on EN487 we did not have specialized personnel. Wu-Jung Lee and Cindy Sellers were trained in the basics of the e-log system, which operated very well with little oversight. Overall, the electronic event log approach proved extremely useful and the Elog software enabled everyone on board to produce a detailed, accurate event log.

12. Outreach

Kaylyn Becker

A blog entitled 'The Krill Blog' was established using the free Blogger host site and associated tools. The goal of this blog was to give real-time updates from the field to describe in a conversational and engaging, but professional, tone for the public our work on krill, including where we were, what we were doing, and why, as well as information on life at sea and oceanographic research more generally. Different science party personnel contributed to the blog over the course of the cruise and a variety of photographs were posted (mostly small in size due to bandwidth issues). As Chief Scientist, Gareth Lawson checked over each post prior to its being uploaded. This cruise we had more science party members participate and averaged a blog post every day on the cruise. We also added more pictures and even some videos to make it more interesting. We found that if we assigned each person a blog topic and a day then the blog was updated more often

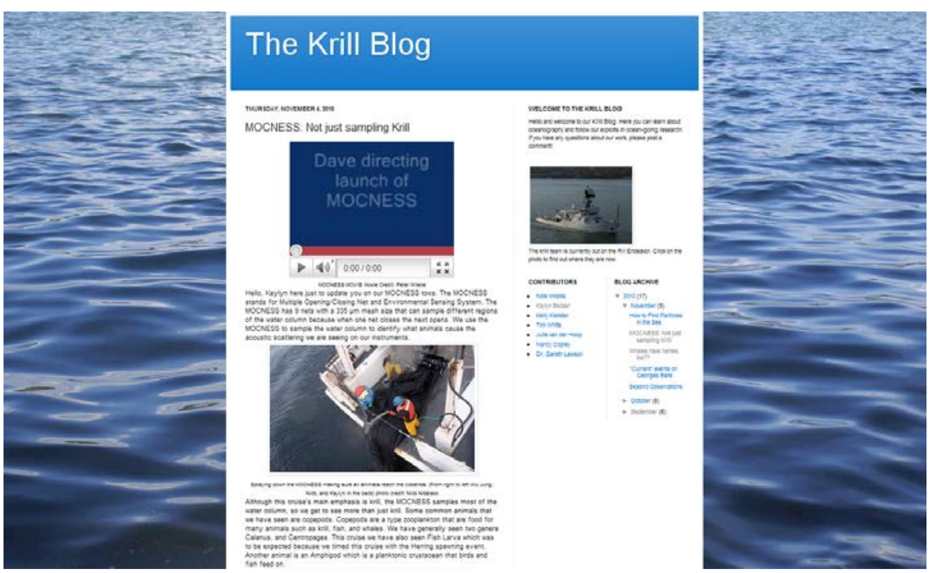

Figure 12.1: The Krill Blog (www.funwithkrill.blogspot.com)

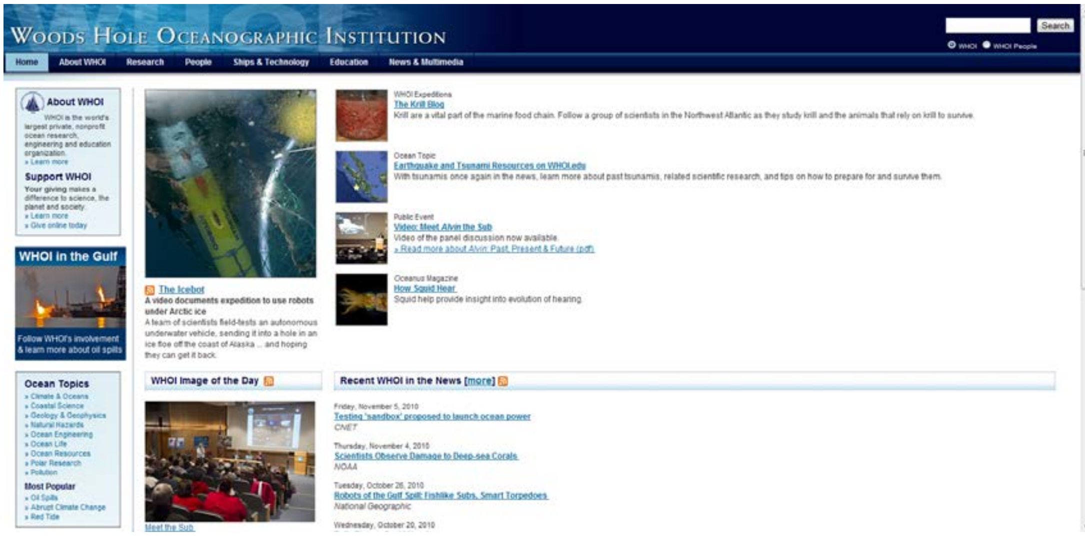

Figure 12.2: The Woods Hole Oceanographic Institution Homepage (www.whoi.edu) posted a link to the Krill Blog.

13. Cruise Participants

Science Party

	NAME	TITLE	AFFILIATION	TEAM
1	Gareth Lawson	Chief Scientist	WHOI	Zooplankton - Day
2	Peter Wiebe	Scientist	WHOI	Zooplankton - Night
3	Cynthia Sellers	Technician	WHOI	Zooplankton - Night
4	Philip Alatalo	Technician	WHOI	Zooplankton - Night
5	Wu-Jung Lee	Grad student	WHOI	Zooplankton - Day
6	Nicholas Woods	Grad student	WHOI	Zooplankton - Day
7	Kaylyn Becker	Volunteer	GMRI	Zooplankton - Day
8	Nicholas Nidzieko	Postdoc	WHOI	Zooplankton - Night
9	Reny Tyson	Grad student	Duke	Top Predators
10	Kelly Kleister	Volunteer	WHOI	Top Predators
11	Timothy White	Grad student	CUNY	Top Predators
12	David Nelson	Marine Technician	URI	

EN487 Science Party. Back, left to right: Cindy Sellers, Nick Woods, Nick Nidzieko. Middle: Gareth Lawson, Phil Alatalo, Kelly Kleister, Kaylyn Becker, Reny Tyson, Tim White. Front: Peter Wiebe, Wu -Jung Lee.

Officers and Crew

	NAME	TITLE
1	Everett McMann	Captain
2	Tom Dornhofer	Chief Engineer
3	Richard Chase III	Chief Mate
4	Shanna Post-Maher	Second Mate
5	George Maltby	QMED
6	Bruce Bannick	QMED
7	Patrick Quigley	Boatswain
8	Paul Rousell	A/B
9	Kevin Walsh	A/B
10	S. Oscar Sisson	A/B
11	Jim Montminy	A/B
12	Jeff Avery	Chief Steward
13	Kim Heine	Messman

Appendix 1. Summary of MOCNESS tow data

Station	Tow	Month local	Day local	Ttime local	Time start/ end (yearday.time)	Lat. (N) start/end	Long.(W) start/end	strobe on/off	Net: depth_open-depth_closed	Volume filtered (m^3)	Comments
1	1	11	1	1336	305.56705	42.07810	-67.79168	on	net 0: 1.6-185.4	1756	
				1444	305.61449	42.12053	-67.80250		net 1: 164.5-189.4	327	
									net 2: 148.0-163.4	301	
									net 3: 115.0-147.3	371	volfilt corrected, 17Nov10
									net 4: 99.7-117.7	192	volfilt corrected, 17Nov10
									net 5: 61.0-99.2	339	volfilt corrected, 17Nov10
									net 6: 48.5-61.4	242	volfilt corrected, 17Nov10
									net 7: 23.0-47.9	317	
									net 8: -0.7-22.5	377	
2	2	11	1	2006	305.83756	42.06253	-67.78280	on	net 0: -1-190	1001	volfilt corrected, 17Nov10
				2139	305.89568	42.10527	-67.80288		net 1: 163-190	320	
									net 2: 149-163	295	
									net 3: 115-152	327	
									net 4: 101-115	345	
									net 5: 74-100	267	
									net 6: 45-73	382	
									net 7: 24-48	258	
									net 8: 0-23	289	
3	3	11	2	2132	306.89745	42.09745	-67.79205	off	net 0: -1-194	1154	
				2310	306.96590	42.13947	-67.81168		net 1: 155-193	407	
									net 2: 105-154	579	
									net 3: 54-105	429	
									net 4: 30-56	458	
									net 5: 31-55	378	

Station	Tow	Month local	Day local	Ttime local	Time start/ end (yearday.time)	Lat. (N) start/end	Long.(W) start/end	strobe on/off	Net: depth_open-depth_closed	Volume filtered (m^3)	Comments
									net 6: 30-55	402	
									net 7: 31-55	401	
									net 8: 0-32	246	
4	4	11	3	1512	307.63329	42.22883	-67.83640	off	net 0: 6-230	1352	
				1634	307.69059	42.20303	-67.77520		net 1: 201-226	511	
									net 2: 151-200	649	
									net 3: 126-150	378	
									net 4: 100-125	294	
									net 5: 76-100	500	
									net 6: 51-75	289	
									net 7: 22-51	307	
									net 8: -1-21	380	volfilt corrected, 17Nov10
5	5	11	3	2143	307.90473	42.17720	-67.82843	off	net 0: -1-226	1302	
				2303	307.96065	42.22138	-67.84557		net 1: 174-224	376	
									net 2: 151-173	395	
									net 3: 126-150	406	
									net 4: 99-126	408	
									net 5: 72-100	378	
									net 6: 48-70	268	
									net 7: 25-47	324	
									net 8: 0-25	403	
6	6	11	5	0916		41.97795	-70.32797	off	no sample; flow calibration only		
				1107		41.97998	-70.33460				

Appendix 2. Event Log

Event number = local date (year, month, day).local time; T = transect number; Seafloor = depth of water in meters

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101028.0855	0855	41.49222	-71.41872	Cruise	start	NaN	NaN	NaN	NaN	NaN	leave port
20101028.1903	1903	41.96745	-70.30422	Hammarhead	start	NaN	NaN	1	NaN	aLavery	calibration - bar in hole 1
20101028.2057	2057	41.96732	-70.29943	Hammarhead	end	NaN	NaN	1	NaN	aLavery	nd
20101028.2058	2057	41.96737	-70.29938	Hammarhead	start	NaN	NaN	2	NaN	aLavery	detached bar
20101029.0002	0002	41.95488	-70.26430	Hammarhead	end	NaN	NaN	2	NaN	aLavery	nd
20101029.0003	0002	41.95490	-70.26420	Hammarhead	start	NaN	NaN	3	NaN	aLavery	repositioned bar to hole 2
20101029.0210	0210	41.95667	-70.25643	Hammarhead	end	NaN	NaN	3	NaN	aLavery	nd
20101029.0246	0245	41.99132	-70.31110	Hammarhead	start	NaN	NaN	4	NaN	aLavery	repositioned bar to hole 3 lat=41.99132
20101029.0544	0544	41.99422	-70.30755	Hammarhead	end	NaN	NaN	4	NaN	aLavery	nd
20101029.0548	0547	41.99398	-70.30848	Hammarhead	start	NaN	NaN	5	NaN	aLavery	moved spheres to starboard side under L M HH
20101029.0855	0854	42.01653	-70.32195	Hammarhead	end	NaN	NaN	5	NaN	aLavery	nd
20101029.1026	1018	41.99273	-70.18503	VPR	start	NaN	0	1	34.2	gLawson	Start time estimated
20101029.1027	1026	41.99257	-70.18522	VPR	end	NaN	0	1	34.47	gLawson	nd
20101029.1305	1304	41.98368	-70.18148	GreeneBomber	start	NaN	NaN	1	34.69	gLawson	First Test after repairs
20101029.1327	1327	41.98118	NaN	Hammarhead	start	NaN	NaN	6	NaN	aLavery	Testing master trigger system and noise evaluation
20101029.1506	1506	42.05052	-70.31898	Hammarhead	end	NaN	NaN	6	NaN	aLavery	nd
20101029.1901	NaN	42.09815	-69.46007	GreeneBomber	end	NaN	NaN	1	177.68	gLawson	check time and location for ending test run
20101030.0340	0339	42.08065	-67.31985	GreeneBomber	start	1	NaN	2	50.73	gLawson	nd
20101030.0350	0350	42.07470	-67.32300	Transect	start	1	NaN	NaN	NaN	NaN	Transect start at 3:50 local; start position 42.0747; -67.3230
20101030.0903	0903	42.38260	-67.49867	Transect	end	1	NaN	NaN	NaN	NaN	Transect 1 ended at 9:03 local
20101030.1046	1046	42.36597	-67.55690	VPR	start	2	1	2	280	gLawson	cannot change the seafloor depth; should be 280m

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101030.1112	1111	42.36175	-67.56403	VPR	end	2	1	2	277.3	gLawson	seafloor 277.3
20101030.1118	1117	42.36082	-67.56667	Transect	start	2	NaN	NaN	272.5	NaN	seafloor 272.5 on HTI
20101030.1510	1510	42.20830	-67.50458	VPR	start	2	2	3	NaN	gLawson	nd
20101030.1537	1537	42.20628	-67.51758	VPR	end	2	2	3	239.1	gLawson	nd
20101030.1916	1915	42.05180	-67.42815	Transect	end	2	NaN	NaN	47	NaN	Seafloor 47m from HTI
20101030.2137	2136	42.02995	-67.53828	Transect	start	3	NaN	NaN	47	NaN	Seafloor 47m from HTI
20101031.0303	0302	42.34760	-67.66217	Transect	end	3	NaN	NaN	235	NaN	Seafloor 235m
20101031.0428	0427	42.32530	-67.76708	Transect	start	4	NaN	NaN	210	NaN	Seafloor 210m from HTI
20101031.0713	0702	42.16703	-67.71140	VPR	start	4	3	4	197.45	gLawson	nd
20101031.0724	0723	42.16665	-67.71203	VPR	end	4	3	4	NaN	gLawson	nd
20101031.0756	0754	42.14000	-67.69735	ObserverBirds	start	4	NaN	NaN	NaN	tWhite	nd
20101031.0849	0849	42.08518	-67.67722	ObserverBirds	end	4	NaN	NaN	175.68	tWhite	nd
20101031.0854	0854	42.08377	-67.67810	VPR	start	4	4	5	175.39	gLawson	nd
20101031.0911	0911	42.07845	-67.68107	VPR	end	4	4	5	174.38	gLawson	nd
20101031.0927	0926	42.07115	-67.67153	ObserverBirds	start	4	NaN	NaN	171.92	tWhite	nd
20101031.1004	1004	42.03408	-67.65702	ObserverMammals	start	4	NaN	NaN	85.82	rTyson	nd
20101031.1032	1032	42.00662	-67.64752	ObserverMammals	end	4	NaN	NaN	NaN	rTyson	nd
20101031.1033	1033	42.00597	-67.64770	ObserverBirds	end	4	NaN	NaN	NaN	tWhite	nd
20101031.1044	1039	42.00192	-67.64923	VPR	start	4	5	6	53.29	gLawson	nd
20101031.1046	1046	42.00088	-67.64968	VPR	end	4	5	6	NaN	gLawson	nd
20101031.1047	1047	42.00067	-67.64983	Transect	end	4	NaN	NaN	NaN	NaN	nd
20101031.1100	1059	41.99777	-67.66093	ObserverBirds	start	4	NaN	NaN	NaN	tWhite	nd
20101031.1203	1202	41.98683	-67.75485	ObserverBirds	end	5	NaN	NaN	NaN	tWhite	nd
20101031.1206	1205	41.99063	-67.75703	ObserverMammals	start	5	NaN	NaN	NaN	rTyson	nd
20101031.1207	1206	41.99102	-67.75722	Transect	start	5	NaN	NaN	NaN	NaN	nd
20101031.1225	1222	42.00938	-67.76423	ObserverBirds	start	5	NaN	NaN	NaN	tWhite	previous transect was 4 End not 5
20101031.1258	1258	42.04192	-67.77832	ObserverMammals	end	5	NaN	NaN	NaN	rTyson	nd
20101031.1259	1259	42.04195	-67.77862	ObserverBirds	end	5	NaN	NaN	NaN	tWhite	nd

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101031.1313	1313	42.04172	-67.78462	VPR	start	5	6	7	NaN	gLawson	VPR test
20101031.1349	1349	42.04107	-67.79820	VPR	end	5	6	7	182.01	gLawson	nd
20101031.1353	1352	42.04502	-67.79928	ObserverMammals	start	5	NaN	NaN	183.6	rTyson	nd
20101031.1357	1357	42.05025	-67.79932	ObserverBirds	start	5	NaN	NaN	186.35	tWhite	nd
20101031.1514	1514	42.13882	-67.81343	ObserverMammals	end	5	NaN	NaN	204.61	rTyson	nd
20101031.1515	1515	42.13983	-67.81390	ObserverBirds	end	5	NaN	NaN	205.35	tWhite	nd
20101031.1526	1526	42.14363	-67.81972	VPR	start	5	7	8	208.02	gLawson	nd
20101031.1544	1544	42.14545	-67.82693	VPR	end	5	7	8	NaN	gLawson	nd
20101031.1554	1554	42.15085	-67.83115	ObserverBirds	start	5	NaN	NaN	NaN	tWhite	nd
20101031.1556	1556	42.15265	-67.83142	ObserverMammals	start	5	NaN	NaN	NaN	rTyson	nd
20101031.1601	1600	42.15797	-67.83162	ObserverMammals	end	5	NaN	NaN	NaN	rTyson	conditions too rough
20101031.1702	1702	42.22248	-67.84498	ObserverBirds	end	5	NaN	NaN	NaN	tWhite	nd
20101031.1705	1705	42.22303	-67.84450	VPR	start	5	8	9	NaN	gLawson	nd
20101031.1725	1725	42.22488	-67.84193	VPR	end	5	8	9	241.66	gLawson	nd
20101031.1905	1905	42.30108	-67.87757	VPR	start	5	9	10	8.8	gLawson	nd
20101031.1928	1928	42.30433	-67.87750	VPR	end	5	9	10	NaN	gLawson	nd
20101031.1929	1929	42.30440	-67.87747	Transect	end	5	NaN	NaN	NaN	NaN	nd
20101031.2109	2109	42.28130	-67.98335	Transect	start	6	NaN	NaN	195.96	NaN	nd
20101031.2110	2109	42.28140	-67.98333	VPR	start	6	10	11	196	gLawson	nd
20101031.2132	2132	42.28380	-67.98003	VPR	end	6	10	11	194.99	gLawson	nd
20101101.0305	0305	41.96103	-67.86292	Transect	end	6	NaN	NaN	NaN	NaN	nd
20101101.0455	0454	42.04063	-67.77665	Transect	start	7	NaN	NaN	NaN	NaN	start of bow tie
20101101.0658	0645	42.11285	-67.78667	Transect	end	7	NaN	NaN	NaN	NaN	nd
20101101.0659	0645	42.11257	-67.78595	Transect	start	8	NaN	NaN	NaN	NaN	nd
20101101.0805	0804	42.07898	-67.70413	ObserverBirds	start	8	NaN	NaN	NaN	tWhite	nd
20101101.0831	0831	42.06485	-67.66797	Transect	end	8	NaN	NaN	NaN	NaN	nd
20101101.0832	0832	42.06477	-67.66740	Transect	start	9	NaN	NaN	NaN	NaN	Transect end missing; time and position same as next transect start

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101101.0833	0833	42.06512	-67.66515	ObserverBirds	end	9	NaN	NaN	NaN	tWhite	nd
20101101.0849	0849	42.07957	-67.67347	ObserverMammals	start	9	NaN	NaN	NaN	rTyson	nd
20101101.0854	0854	42.08600	-67.67473	ObserverBirds	start	9	NaN	NaN	NaN	tWhite	nd
20101101.0915	0915	42.10690	-67.68483	ObserverMammals	end	9	NaN	NaN	NaN	rTyson	nd
20101101.0945	0945	42.13485	-67.69543	ObserverBirds	end	9	NaN	NaN	NaN	tWhite	nd
20101101.1002	1000	42.14050	-67.69207	VPR	start	9	11	12	193.04	gLawson	nd
20101101.1024	1022	42.14743	-67.69227	VPR	end	9	11	12	192.19	gLawson	nd
20101101.1036	1036	42.15178	-67.69373	Transect	end	9	NaN	NaN	313.88	NaN	entry made post-cruise by BCO-DMO
20101101.1037	1037	42.15178	-67.69373	Transect	start	10	NaN	NaN	313.88	NaN	nd
20101101.1048	1048	42.14053	-67.70010	ObserverBirds	start	10	NaN	NaN	8.31	tWhite	nd
20101101.1138	1137	42.09927	-67.73015	ObserverBirds	end	10	NaN	NaN	NaN	tWhite	nd
20101101.1205	1204	42.07727	-67.74682	ObserverBirds	start	10	NaN	NaN	NaN	tWhite	nd
20101101.1236	1236	42.05357	-67.76862	ObserverBirds	end	10	NaN	NaN	NaN	tWhite	nd
20101101.1249	1249	42.04132	-67.77630	Transect	end	10	NaN	NaN	NaN	NaN	nd
20101101.1306	1249	42.05370	-67.78183	Transect	start	11	NaN	NaN	NaN	NaN	Missing entry for end of this transect line
20101101.1336	1336	42.07810	-67.79168	MOCNESS	start	11	NaN	1	NaN	pWiebe	nd
20101101.1503	1453	42.12053	-67.80250	MOCNESS	end	11	NaN	1	202.42	pWiebe	nd
20101101.1504	1504	42.12033	-67.80215	Transect	end	11	NaN	NaN	201.41	NaN	Transect 11 end entered post-cruise
20101101.1505	1505	42.12033	-67.80215	Transect	start	12	NaN	NaN	201.41	NaN	Transect 11 end missing; time and position same as transect 12 start
20101101.1507	1506	42.11852	-67.79842	ObserverBirds	start	12	NaN	NaN	200.2	tWhite	nd
20101101.1655	1655	42.07125	-67.67333	Transect	end	12	NaN	NaN	NaN	NaN	nd
20101101.1656	1656	42.07138	-67.67313	Transect	start	13	NaN	NaN	NaN	NaN	nd
20101101.1704	1703	42.07893	-67.67467	ObserverBirds	end	13	NaN	NaN	NaN	tWhite	nd
20101101.1803	1803	42.14192	-67.70130	Transect	end	13	NaN	NaN	NaN	NaN	nd
20101101.1804	1803	42.14158	-67.70258	Transect	start	14	NaN	NaN	190	NaN	Seafloor 190m; end of transect 14 missing should be 1943; 42.0496; -67.7766
20101101.1943	1943	42.04960	-67.77660	Transect	end	14	NaN	NaN	NaN	NaN	Transect 14 end entered post-cruise

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101101.1944	1944	42.04960	-67.77660	Transect	start	15	NaN	NaN	NaN	NaN	Transect 15 start entered post-cruise
20101101.2016	2015	42.06253	-67.78280	MOCNESS	start	15	NaN	2	NaN	pWiebe	nd
20101101.2140	2131	42.10527	-67.80288	MOCNESS	end	15	NaN	2	202.18	pWiebe	nd
20101101.2208	2208	42.12302	-67.81272	Transect	end	15	NaN	NaN	202.64	NaN	start of trransect 15 is missing should be 1943; 42.0496; -67.7766
20101101.2209	2209	42.12318	-67.81283	Transect	start	16	NaN	NaN	203.31	NaN	nd
20101101.2359	2359	42.06802	-67.66887	Transect	end	16	NaN	NaN	NaN	NaN	a few minutes late
20101102.0000	0000	42.06860	-67.66908	Transect	start	17	NaN	NaN	NaN	NaN	a few minutes late
20101102.0114	0114	42.14230	-67.69993	Transect	end	17	NaN	NaN	NaN	NaN	nd
20101102.0115	0115	42.14183	-67.70013	Transect	start	18	NaN	NaN	NaN	NaN	nd
20101102.0255	0255	42.04160	-67.77715	Transect	end	18	NaN	NaN	NaN	NaN	nd
20101102.0256	0256	42.04155	-67.77760	Transect	start	19	NaN	NaN	NaN	NaN	nd
20101102.0408	0408	42.11917	-67.80543	Transect	end	19	NaN	NaN	NaN	NaN	nd
20101102.0409	0409	42.11943	-67.80512	Transect	start	20	NaN	NaN	NaN	NaN	nd
20101102.0559	0559	42.07882	-67.67375	Transect	end	20	NaN	NaN	NaN	NaN	nd
20101102.0609	0609	42.07918	-67.67392	Transect	start	21	NaN	NaN	NaN	NaN	nd
20101102.0717	0717	42.13928	-67.70370	Transect	end	21	NaN	NaN	NaN	NaN	nd
20101102.0718	0718	42.13913	-67.70387	Transect	start	22	NaN	NaN	NaN	NaN	nd
20101102.0723	0722	42.13607	-67.70535	Hammarhead	start	22	NaN	1	NaN	aLavery	nd
20101102.0752	0752	42.10667	-67.72417	ObserverBirds	start	22	NaN	NaN	NaN	tWhite	nd
20101102.0950	0950	42.02952	-67.78898	Transect	end	22	NaN	NaN	NaN	NaN	nd
20101102.0951	0951	42.02982	-67.78875	Transect	start	23	NaN	NaN	NaN	NaN	nd
20101102.1015	1015	42.04930	-67.77532	ObserverBirds	start	23	NaN	NaN	NaN	tWhite	nd
20101102.1124	1124	42.11295	-67.80700	ObserverBirds	end	23	NaN	NaN	NaN	tWhite	nd
20101102.1140	1140	42.11393	-67.81087	Transect	end	23	NaN	NaN	203.68	NaN	nd
20101102.1141	1141	42.11403	-67.81105	VPR	start	23	12	13	204.39	gLawson	nd
20101102.1204	1204	42.11827	-67.81632	VPR	end	23	12	13	204.09	gLawson	nd
20101102.1223	1223	42.12165	-67.81593	Hammarhead	end	23	NaN	1	205.41	aLavery	nd

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101102.1225	1224	42.12123	-67.81372	Transect	start	24	NaN	NaN	203.57	NaN	nd
20101102.1237	1237	42.11583	-67.79753	ObserverBirds	start	24	NaN	NaN	199.37	tWhite	nd
20101102.1324	1324	42.09310	-67.73815	ObserverBirds	end	24	NaN	NaN	185.83	tWhite	nd
20101102.1332	1331	42.09395	-67.73622	VPR	start	24	13	14	186.62	gLawson	nd
20101102.1407	1350	42.08328	-67.71463	VPR	end	24	13	14	NaN	gLawson	nd
20101102.1446	1445	42.06487	-67.67082	ObserverMammals	end	24	NaN	NaN	NaN	rTyson	nd
20101102.1447	1447	42.06480	-67.66932	Transect	end	24	NaN	NaN	NaN	NaN	nd
20101102.1448	1448	42.06488	-67.66917	Transect	start	25	NaN	NaN	NaN	NaN	nd
20101102.1451	1451	42.06598	-67.66902	Hammarhead	start	25	NaN	2	NaN	aLavery	nd
20101102.1459	1458	42.06827	-67.66937	VPR	start	25	14	15	168.49	gLawson	nd
20101102.1514	1514	42.07218	-67.66927	VPR	end	25	14	15	170.92	gLawson	nd
20101102.1535	1534	42.08870	-67.67633	ObserverBirds	start	25	NaN	NaN	NaN	tWhite	nd
20101102.1547	1547	42.10023	-67.68142	ObserverMammals	start	25	NaN	NaN	NaN	rTyson	nd
20101102.1632	1631	42.14053	-67.69838	ObserverMammals	end	25	NaN	NaN	NaN	rTyson	nd
20101102.1635	1635	42.14158	-67.69897	ObserverBirds	end	25	NaN	NaN	NaN	tWhite	nd
20101102.1637	1637	42.14198	-67.69917	Transect	end	25	NaN	NaN	NaN	NaN	nd
20101102.1638	1638	42.14205	-67.69918	Transect	start	26	NaN	NaN	NaN	NaN	nd
20101102.1646	1645	42.14428	-67.69975	VPR	start	26	15	16	NaN	gLawson	nd
20101102.1705	1705	42.14698	-67.70120	VPR	end	26	15	16	195.08	gLawson	nd
20101102.1918	1918	42.04430	-67.77763	VPR	start	26	16	17	NaN	gLawson	nd
20101102.1920	1920	42.04453	-67.77730	Transect	end	26	NaN	NaN	NaN	NaN	nd
20101102.1938	1937	42.04780	-67.77770	VPR	end	26	16	17	NaN	gLawson	nd
20101102.2150	2149	42.09745	-67.79205	MOCNESS	start	27	NaN	3	NaN	pWiebe	nd
20101102.2151	2150	42.09770	-67.79222	Transect	start	27	NaN	NaN	200.44	NaN	actually started near end of VPR
20101102.2312	2312	42.13947	-67.81168	MOCNESS	end	27	NaN	3	NaN	pWiebe	nd
20101102.2323	2323	42.14437	-67.81418	Hammarhead	end	27	NaN	2	NaN	aLavery	nd
20101102.2352	2352	42.15525	-67.82122	Transect	end	27	NaN	NaN	NaN	NaN	line extends past bowtie1 corner to bowtie2
20101102.2353	2352	42.15582	-67.82153	Transect	start	28	NaN	NaN	NaN	NaN	bowtie2 start

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101103.0110	0110	42.23447	-67.84893	Transect	end	28	NaN	NaN	NaN	NaN	nd
20101103.0111	0110	42.23392	-67.84768	Transect	start	29	NaN	NaN	234	NaN	Seafloor 234m
20101103.0252	0252	42.17867	-67.71348	Transect	end	29	NaN	NaN	190	NaN	Seafloor 190m
20101103.0253	0253	42.17932	-67.71313	Transect	start	30	NaN	NaN	NaN	NaN	nd
20101103.0412	0412	42.25625	-67.74458	Transect	end	30	NaN	NaN	222	NaN	Seafloor 222m
20101103.0413	0413	42.25600	-67.74518	Transect	start	31	NaN	NaN	NaN	NaN	nd
20101103.0605	0605	42.16060	-67.82550	Transect	end	31	NaN	NaN	NaN	NaN	nd
20101103.0606	0606	42.16090	-67.82557	Transect	start	32	NaN	NaN	NaN	NaN	bowtie2 pass2
20101103.0713	0713	42.23437	-67.84963	Transect	end	32	NaN	NaN	NaN	NaN	nd
20101103.0714	0714	42.23437	-67.84910	Transect	start	33	NaN	NaN	NaN	NaN	nd
20101103.0726	0726	42.22695	-67.83048	ObserverBirds	start	33	NaN	NaN	NaN	tWhite	nd
20101103.0729	0729	42.22547	-67.82728	ObserverMammals	start	33	NaN	NaN	NaN	rTyson	nd
20101103.0852	0852	42.17918	-67.71065	Transect	end	33	NaN	NaN	NaN	NaN	nd
20101103.0853	0853	42.17947	-67.71068	Transect	start	34	NaN	NaN	NaN	NaN	nd
20101103.0900	0900	42.18663	-67.71572	ObserverBirds	end	33	NaN	NaN	NaN	tWhite	nd
20101103.0901	0901	42.18753	-67.71607	ObserverBirds	start	34	NaN	NaN	NaN	tWhite	nd
20101103.1001	1001	42.25758	-67.74373	Transect	end	34	NaN	NaN	NaN	NaN	nd
20101103.1002	1002	42.25783	-67.74373	Transect	start	35	NaN	NaN	NaN	NaN	nd
20101103.1005	1005	42.25993	-67.74388	ObserverMammals	end	34	NaN	NaN	NaN	rTyson	nd
20101103.1008	1007	42.26037	-67.74387	ObserverBirds	end	34	NaN	NaN	NaN	tWhite	nd
20101103.1017	1017	42.26268	-67.74357	VPR	start	35	17	18	231.13	gLawson	nd
20101103.1043	1043	42.27137	-67.74460	VPR	end	35	17	18	230.39	gLawson	nd
20101103.1052	1052	42.26648	-67.74518	ObserverMammals	start	35	NaN	NaN	232.39	rTyson	nd
20101103.1057	1057	42.26105	-67.74468	ObserverBirds	start	35	NaN	NaN	230.18	tWhite	nd
20101103.1137	1137	42.21785	-67.77270	ObserverMammals	end	35	NaN	NaN	230.85	rTyson	nd
20101103.1138	1138	42.21752	-67.77293	ObserverBirds	end	35	NaN	NaN	230.73	tWhite	nd
20101103.1204	1203	42.20810	-67.78040	VPR	start	35	18	19	228.9	gLawson	nd
20101103.1224	1224	42.21185	-67.78087	VPR	end	35	18	19	NaN	gLawson	nd

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101103.1238	1238	42.19967	-67.78877	ObserverMammals	start	35	NaN	NaN	NaN	rTyson	nd
20101103.1239	1239	42.19892	-67.78933	ObserverBirds	start	35	NaN	NaN	NaN	tWhite	nd
20101103.1325	1325	42.15760	-67.81975	ObserverBirds	end	35	NaN	NaN	NaN	tWhite	nd
20101103.1326	1326	42.15723	NaN	ObserverMammals	end	35	NaN	NaN	NaN	rTyson	nd
20101103.1331	1331	42.15795	-67.82165	VPR	start	35	19	20	NaN	gLawson	nd
20101103.1348	1348	42.16107	-67.82173	VPR	end	35	19	20	213.15	gLawson	nd
20101103.1353	1353	42.16358	-67.82333	Transect	end	35	NaN	NaN	214.54	NaN	nd
20101103.1354	1354	42.16375	-67.82343	Transect	start	36	NaN	NaN	213.05	NaN	nd
20101103.1400	1359	42.17025	-67.82663	ObserverMammals	start	36	NaN	NaN	218.23	rTyson	nd
20101103.1406	1406	42.17762	-67.82948	ObserverBirds	other	36	NaN	NaN	223.05	tWhite	mocness
20101103.1458	1458	42.23450	-67.85092	ObserverMammals	end	36	NaN	NaN	238.59	rTyson	nd
20101103.1459	1459	42.23445	-67.84965	Transect	end	36	NaN	NaN	238.26	NaN	nd
20101103.1500	1500	42.23438	-67.84947	Transect	start	37	NaN	NaN	238.41	NaN	nd
20101103.1511	1511	42.22883	-67.83640	MOCNESS	start	37	NaN	4	239.34	pWiebe	nd
20101103.1632	1632	42.20507	-67.77975	ObserverBirds	end	37	NaN	NaN	227.02	tWhite	mocness
20101103.1638	1638	42.20303	-67.77520	MOCNESS	end	37	NaN	4	223.1	pWiebe	nd
20101103.1649	1648	42.19860	-67.76497	ObserverMammals	start	37	NaN	NaN	218.63	rTyson	nd
20101103.1700	1656	42.19253	-67.74860	ObserverBirds	start	37	NaN	NaN	212.52	tWhite	nd
20101103.1723	1723	42.18020	-67.71822	ObserverMammals	end	37	NaN	NaN	199.31	rTyson	nd
20101103.1724	1724	42.18017	-67.71812	ObserverBirds	end	37	NaN	NaN	196.45	tWhite	nd
20101103.1727	1727	42.17933	-67.71318	Transect	end	37	NaN	NaN	NaN	NaN	nd
20101103.1728	1728	42.17988	-67.71317	Transect	start	38	NaN	NaN	NaN	NaN	nd
20101103.1847	1847	42.25600	-67.74348	Transect	end	38	NaN	NaN	NaN	NaN	nd
20101103.1848	1848	42.25602	-67.74393	Transect	start	39	NaN	NaN	NaN	NaN	nd
20101103.1954	1953	42.19592	-67.78933	Handline	start	39	NaN	NaN	NaN	gLawson	near middle of bowtie
20101103.2017	2017	42.19480	-67.78763	Handline	end	39	NaN	NaN	NaN	gLawson	no fish today
20101103.2033	2033	42.19190	-67.78975	Hammarhead	start	39	NaN	3	NaN	aLavery	nd
20101103.2124	2123	42.15528	-67.82278	Transect	end	39	NaN	NaN	NaN	NaN	nd

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101103.2125	2125	42.15600	-67.82447	Transect	start	40	NaN	NaN	NaN	NaN	nd
20101103.2147	2147	42.17720	-67.82843	MOCNESS	start	40	NaN	5	NaN	pWiebe	nd
20101103.2307	2307	42.22138	-67.84557	MOCNESS	end	40	NaN	5	NaN	pWiebe	nd
20101103.2326	2325	42.23555	-67.85018	Transect	end	40	NaN	NaN	NaN	NaN	nd
20101103.2329	2329	42.23710	-67.84757	Transect	start	41	NaN	NaN	NaN	NaN	nd
20101104.0117	0117	42.17995	-67.71230	Transect	end	41	NaN	NaN	NaN	NaN	nd
20101104.0118	0118	42.18013	-67.71210	Transect	start	42	NaN	NaN	NaN	NaN	nd
20101104.0227	0227	42.25737	-67.74383	Transect	end	42	NaN	NaN	NaN	NaN	nd
20101104.0228	0228	42.25693	-67.74453	Transect	start	43	NaN	NaN	NaN	NaN	nd
20101104.0405	0405	42.15617	-67.82130	Transect	end	43	NaN	NaN	NaN	NaN	nd
20101104.0408	0408	42.15755	-67.82455	Transect	start	44	NaN	NaN	NaN	NaN	nd
20101104.0514	0514	42.23295	-67.84930	Transect	end	44	NaN	NaN	NaN	NaN	nd
20101104.0517	0517	42.23417	-67.84678	Transect	start	45	NaN	NaN	NaN	NaN	nd
20101104.0632	0628	42.19655	-67.75393	Hammarhead	end	45	NaN	3	NaN	aLavery	recovery to take the Nortek ADCP off
20101104.0635	0635	42.19655	-67.75267	Hammarhead	start	45	NaN	4	NaN	aLavery	nd
20101104.0706	0706	42.18470	-67.71802	Transect	end	45	NaN	NaN	NaN	NaN	nd
20101104.0707	0707	42.18503	-67.71802	Transect	start	46	NaN	NaN	NaN	NaN	nd
20101104.0717	0716	42.19703	-67.72040	ObserverMammals	start	46	NaN	NaN	NaN	rTyson	nd
20101104.0750	0750	42.23343	-67.73282	ObserverBirds	start	46	NaN	NaN	NaN	tWhite	nd
20101104.0802	0802	42.24640	-67.73687	ObserverMammals	end	46	NaN	NaN	NaN	rTyson	nd
20101104.0803	0803	42.24692	-67.73678	ObserverBirds	end	46	NaN	NaN	NaN	tWhite	nd
20101104.0808	0808	42.24620	-67.73528	Hammarhead	end	46	NaN	4	NaN	aLavery	nd
20101104.0828	0824	42.24227	-67.72930	GreeneBomber	end	46	NaN	2	NaN	gLawson	nd
20101104.0850	0849	42.24640	-67.79905	ObserverBirds	start	46	NaN	NaN	NaN	tWhite	nd
20101104.1123	1123	42.27650	-68.46897	ObserverBirds	end	46	NaN	NaN	182.44	tWhite	nd
20101104.1218	1217	42.28793	-68.67898	ObserverBirds	start	46	NaN	NaN	208.66	tWhite	nd
20101104.1326	1326	42.29972	-68.93545	ObserverBirds	end	46	NaN	NaN	214.51	tWhite	nd
20101104.1348	1347	42.30343	-69.01233	ObserverBirds	start	46	NaN	NaN	207.75	tWhite	nd

Event	Time Local	Latitude	Longitude	Instrument	Action	T	Station	Cast	Seafloor	PI_name	Comment
20101104.1500	1500	42.31453	-69.26620	ObserverBirds	end	46	NaN	NaN	239.98	tWhite	nd
20101104.1833	0824	42.32395	-69.52895	Transect	end	46	NaN	NaN	241.23	NaN	Entered many hours after the actual event.
20101105.0844	0844	41.97847	-70.32737	GreeneBomber	start	NaN	NaN	3	47.01	gLawson	nd
20101105.0916	0916	41.97795	-70.32797	MOCNESS	start	NaN	NaN	6	47.29	pWiebe	calibration of MOCNESS flowmeter
20101105.1107	1107	41.97998	-70.33460	MOCNESS	end	NaN	NaN	6	NaN	pWiebe	end calibration run
20101105.1133	1132	41.98077	-70.32763	GreeneBomber	end	NaN	NaN	3	NaN	gLawson	nd
20101105.1243	1242	41.95627	-70.32343	Hammarhead	start	NaN	NaN	5	NaN	aLavery	calibration in Cape Cod Bay
20101105.1453	1453	42.00560	-70.31327	Hammarhead	end	NaN	NaN	5	NaN	aLavery	nd
20101106.0735	0735	41.49237	-71.41860	Cruise	end	NaN	NaN	NaN	9.99	NaN	nd