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Characterization of Essential Fish Habitat In the Western Gulf of Maine

A final report

to

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SUMMARY

Fishermen, representing a variety of commercial fishing activities, were interviewed to provide a basis for the selection of two study sites for an assessment of essential fish habitat. The fishermen made recommendations of possible study areas based on their historical knowledge of where the most productive areas were located. This, and additional GIS information, led to the selection of one site on the western edge of the Gulf of Maine Permanent Closure Area called Pigeon Hills, and another called Long Bank, just off the southwestern corner of the Stellwagen National Marine Sanctuary. In both cases the study areas consisted of east- west rectangular transects which crossed the boundary of the respective controlled areas.

The sites, both approximately 10 km^2, were surveyed using a 125-kHz GeoAcoustics GeoSwath bathymetry system, and an Edgetech 272 TD towfish side scan sonar. All survey work was conducted from commercial fishing vessels during the fall of 2004 and the spring of 2005. Habitat conditions were evaluated using a towed video sled, a drift camera, and a mini- ROV. At the southern site, benthic grab samples were collected at seven stations within the study area and at two stations in a reference area, 5 km to the WSW. The area to the southwest had been surveyed in a previous CRPP project on the effects of bottom trawling. Grab samples were used to characterize the benthic infaunal communities and sediment texture. Baited underwater video systems were placed at a variety of locations for periods of up to 24 hours while other survey work was in progress. Profiles of the water column were taken at various stations throughout both study areas in different seasons.

GeoSwath and side scan sonar revealed complex topography at both sites. Depths at the Pigeon Hills site ranged from 29.6 meters at the peak of East Pigeon Hill to 113 meters in a trench bisecting the site. The Pigeon Hills are bedrock ledges or outcrops surrounded by sand, gravel and cobble. The Stellwagen/Long Bank site was characterized by rocky out crops at either end where depths were approximately 30 meters, and an extensive stretch of soft bottom (silty-sand) up to 66 meters depth in between.

The results of 17 video tows at each site were classified according to a habitat classification system proposed by Auster et al (1998). This included a complexity score of from 1, for flat sand and mud bottom to 15, for piled boulders. All eight major bottom habitats as described by Auster et al were found at both sites. A total of 23 invertebrates, 7 fish species and 2 types of red algae were identified in the video sled tapes. In the muddy sand, flat sand and cobble bottom that surrounds Pigeon Hills, burrowing anemones (*Cerianthus*) and sea stars (*Leptasterias* sp) were the dominant epifauna and red hake the dominant fish. On the rock ledge habitat, sea squirts (*Boltenia*) and horse stars (*Hippasteria*) were prominent invertebrates. Rose fish (*Sebastes fasciatus*) were common as were large schools of juvenile pollock.

At the Stellwagen/Long Bank site, the dominant invertebrates epifaunal species in the soft bottom were sea stars and burrowing anemones. The bread crumb sponge (*Halichondria*) was common on the pebble-cobble bottom. Red hake and flounder were observed in the fall survey. Very few fish other than red hake were observed in the spring survey at the Stellwagen/Long Bank transect.

More than 200 species of invertebrates were identified in the soft bottom benthic grab samples from the Stellwagen/Long Bank region. This included 126 species of polychaetes, 23 amphipods, 19 bivalves, 10 gastropods and 7 echinoderms. Three replicate grab samples from each station produced from 76 to 104 species. The total number of individuals ranged from 1,822 to 3,562, representing densities of from 15,177 to 29,671 organisms per square meter. The dominant organisms were small polychaetes such as *Spio limicola*, *Prionospio steenstrupi* and *Anobothrus gracilis*. Bivalves such as *Nucula delphinodonta, Thyasira gouldii* and *Crenella decussata* were also very common. The fauna at the Stellwagen/Long Bank site showed considerable overlap with that identified in the reference site at Mud Hole and at other sites throughout Massachusetts Bay.

Water column profiles highlighted the complexity of the hydrography at both sites. During the period of stratification (May – September) significant differences in the structure of the thermocline were seen over very short distances. Variations in the depth of the thermocline were up to 10 meters. These differences were probably related to currents or internal waves.

Significant logistical problems were encountered during the project. These were due to the seasonal schedule, weather, accessibility to the sites due to fixed gear, and performance of some of the equipment. The drift camera, although producing some good video footage, was not as reliable for completing transects as the video sled. Fish were observed in only two of the baited video sets. The mini ROV was too limited in range and susceptible to strong currents - a feature frequently encountered at both sites. Video sled data were not sufficiently quantitative to enable comparisons of similar habitat type inside and outside the respective boundaries. Due to the seasonality of fish distribution and abundance, fewer fish were seen in this effort than in similar transect work completed in other studies. With limited research cruise time, we were unable to confirm the specific factors that contribute to the productivity of these sites. They undoubtedly include the fact that a wide variety of habitats occur over very small horizontal and vertical distances producing an ecotone effect. Complex hydrography, which might enhance productivity of the areas, is also a factor. The GeoSwath, side scan, and habitat video transects have however provided a good platform for any future research in these two productive areas.

1 INTRODUCTION

In 1996, the Sustainable Fisheries Acts amended the Magnuson-Stevens Fishery Conservation Act to require that fishery management plans describe and identify essential fish habitat (EFH), adverse impacts on EFH, and actions to conserve and advance EFH. The New England Regional Fisheries Management Council established an EFH Technical Team to prepare a separate habitat component to the annual stock assessment and fishery evaluation reports. Current designation of essential fish habitats is based primarily on NMFS seasonal surveys. The variable distribution of fish was examined and the areas of highest catch were deemed preferred habitat (NEFMC, 1999). This was considered level 1 information, which needed to be refined by the acquisition of more detailed information on relative abundance, growth, survival, and production rates associated with different habitats. Basic mapping of various habitat types in most areas is lacking. The first stage is to determine the distribution of each habitat type. From that point, a more detailed analysis of the respective habitats will reveal their relative importance as EFH.

The Western Gulf of Maine Permanent Closure Area has been off limits to commercial fishing for approximately ten years. The value of closures or marine reserves has been debated in the literature and it is only recently that clearer evidence of their potential value has been demonstrated. Willis et al (2003) using baited video reported that density of snapper (a migratory species) within these reserves was up to 14 times higher than found outside the reserves. In addition gamete production within these areas was 19 times higher than surrounding areas because of the higher densities and larger sizes of individuals within the reserves.

Some mapping of the physical habitats within the GOM has taken place. Multibeam surveys have been conducted in the Stellwagen Bank National Marine Sanctuary (Valentine, 2002) and a smaller area in the Great South Channel (Valentine, 2001). Resolution in these multibeam efforts is in the order of 3 - 10 meters, not sufficient to clearly identify key parameters. There is one current Northeast Consortium project that is monitoring physical and biological attributes in a more detailed fashion in the northern part of Jeffrey's Ledge (Grizzle, pers comm.). Other than the standard NMFS survey trawls there has been no detailed effort directed toward assessing fish stocks within the permanently closed area. Coverage of this area needs to be more specific in order for us to understand the reasons for high productivity in certain areas and the potential value of the closed area to the Gulf of Maine as a whole. While there is a need for more broad scale coverage by technologies such as multi-beam, there is also a need for focused detailed studies on certain areas.

An important information source is that of commercial fishermen. In 1999 the Northeast Office of the National marine Fisheries service (NMFS) established the Cooperative Partners Research Program (CRPP), formerly known as Cooperative Research Partners Initiative (CRPI). This purpose of this program is to establish working relationships between scientists and fishermen and take advantage of the knowledge and skills of both groups in collecting data that will facilitate good management of stocks. For many years, areas within the GOM closure were prime fishing grounds and a large number of fishermen fished mainly within those boundaries. Fishermen, through trial and error and communication, have detailed knowledge of where the best fishing areas are and at what times of year. Almost all keep their own maps and notes to go the right places at the right times to maximize their catch. The concept of essential fish habitat incorporates all stages in the life cycle of fish species. In some cases, habitat for spawning or juvenile protection might be considered more critical, but areas that support high abundances of adults must also be significant. The objectives of this project were to locate areas known by the industry to support high fish productivity and then evaluate the physical and biological attributes of these sites to gain some insight as to why the areas might be considered essential fish habitat.

2 SITE SELECTION

Two sites were chosen based on the recommendations of fishermen and geophysical characteristics. Fishermen from a variety of gear types and approaches were interviewed (trawl, longline, gillnet, lobster, and charter boat). Ideally, study areas would consist of transects from within a closed area or sanctuary to an adjacent region open to fishing. Some limitations included the fact that camera gear lines and geoswath penetration restricted site selection to depths of no more than 100 meters. A further consideration was distance from shore since most of the work was to be performed from small vessels (<50 ft.). The size of each site to be surveyed was also dictated by the amount of sidescan and geoswath surveying that could be completed in 8 days due to budget constraints.

2.1 REVIEW OF EXISTING DATA

The project team reviewed existing geophysical and ecological data for the Gulf of Maine, including Stellwagen Bank and Jeffrey's Ledge to assist in the selection of two Study Sites. When possible, existing data was imported to a Geographic Information System (GIS) database to assist spatial evaluation of overlapping information.

2.1.1 USGS MULTIBEAM

The USGS conducted a multibeam bathymetric survey of a large portion of the Gulf of Maine from the fall of 1994 to the fall of 1996 (Valentine et al., 1999a). A digital (CD) copy of processed multibeam bathymetric data was acquired and georeferenced imagery from the USGS survey was imported to GIS software. These data were used to screen potential sites based on depth, suggested substrate composition, and bathymetric relief.

2.1.2 FISHING INTENSITY MAPS

Through the period July 2001 – June 2002, Wiley et al. conducted monthly, standardized shipboard surveys along 15 designated tracklines that bisected the sanctuary in an east/west direction. Tracklines were separated by 5 km and survey speed was 13 knots. Sightings were recorded for marine mammals, commercial fishing vessels, vessels and fixed gear. Commercial fishing vessels were further identified as either stern trawler, side trawler, scallop dredge, gillnet boat, lobster boat, longline boat and other. Data were grouped into 12-month and seasonal time periods. Seasons were: summer; July – September, fall; October – December, winter; January – March and spring; April – June. For fixed gear, representing longline and lobster boats, highest densities were found in the northwest and southwest corners of the Sanctuary (Figure 2.1).

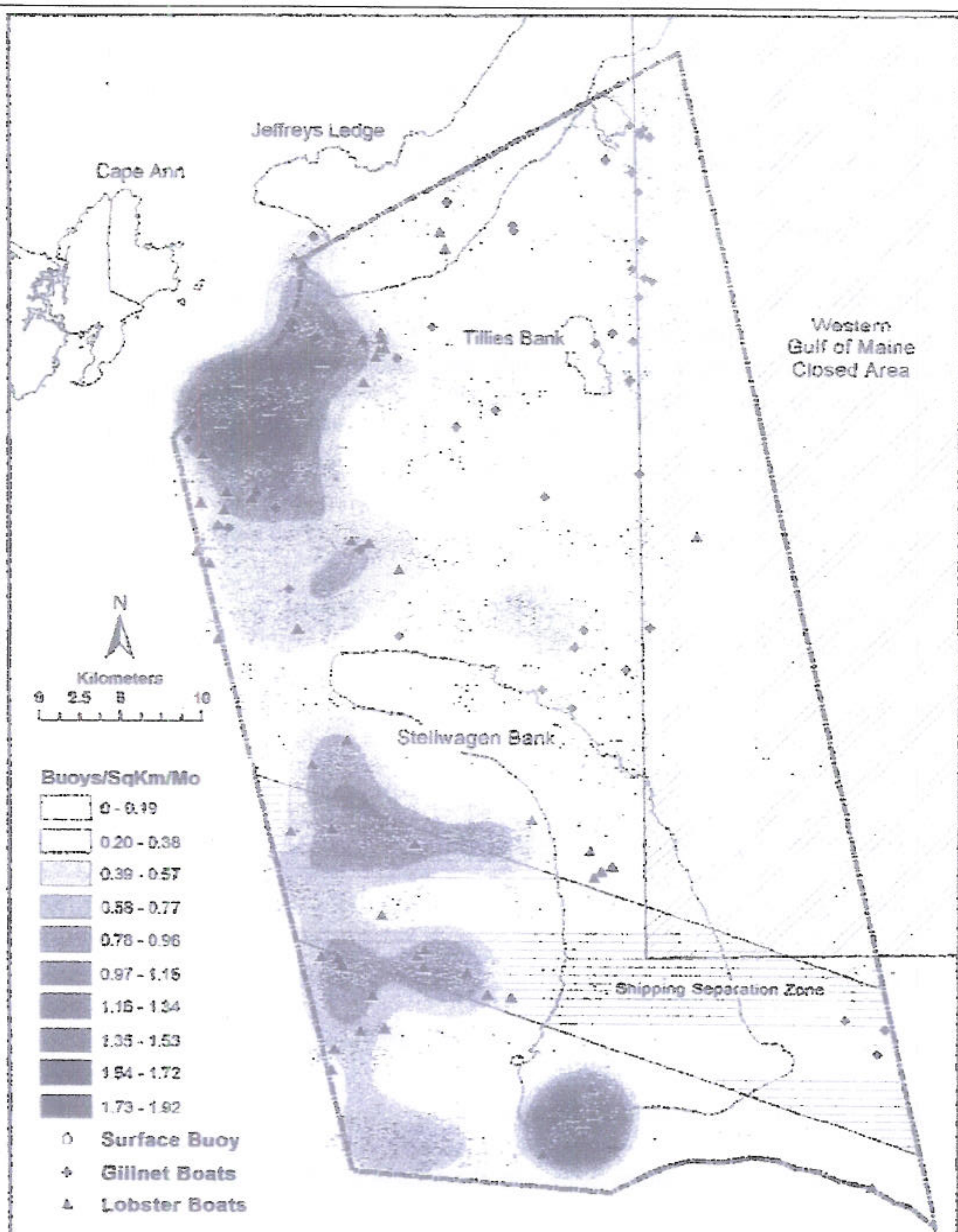


Figure 2.1. Density and distribution of surface buoys from Wiley et al., 2000)

Several useful data layers were obtained from the Massachusetts State GIS System (MA GIS EOEA) and incorporated into the GIS project used to review potential study areas. These layers included NOAA nautical charts, polygons defining regulated areas, and polygons defining the Stellwagen Bank National Marine Sanctuary.

2.2 INTERVIEWS WITH FISHERMEN -

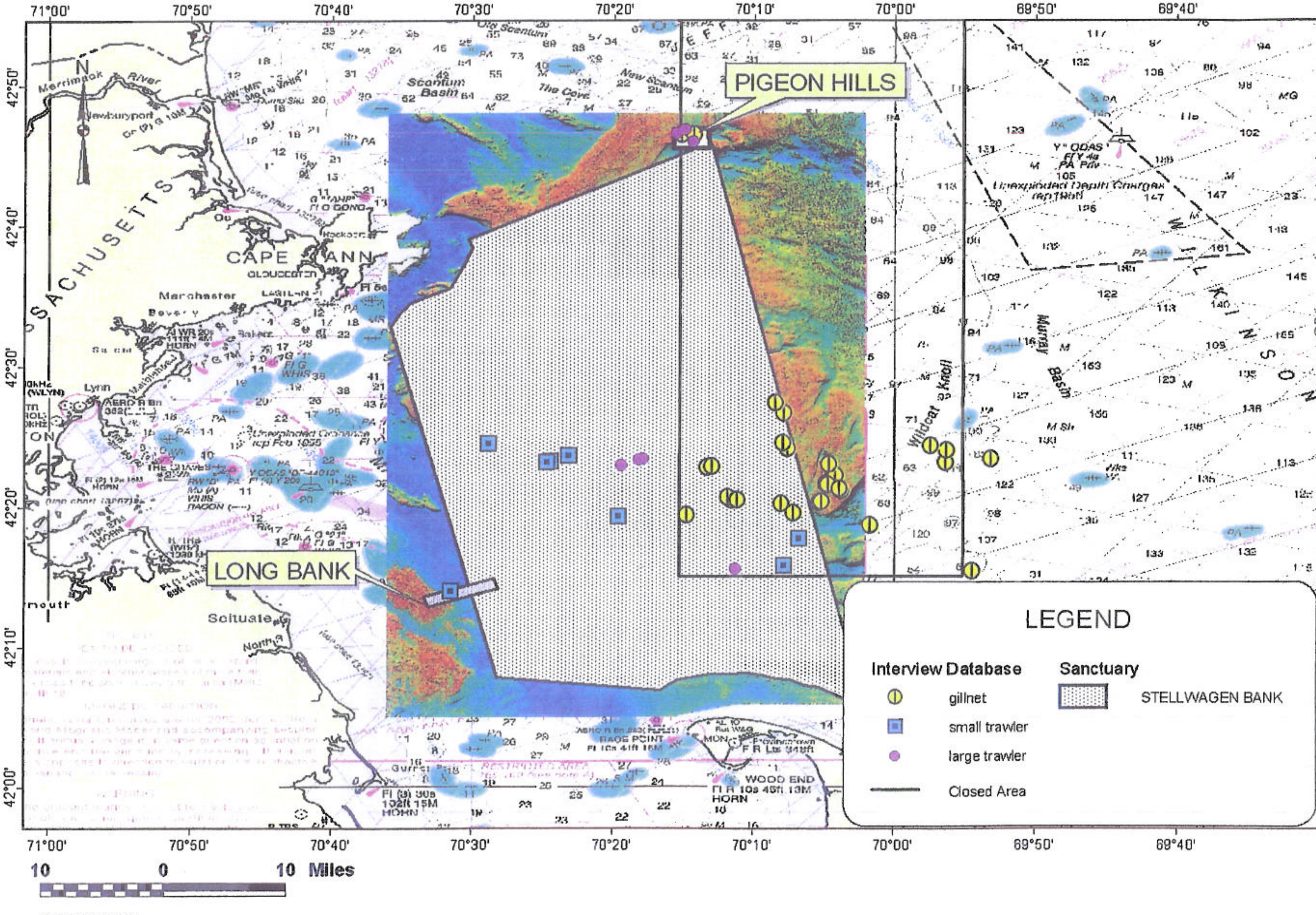
Twenty fishermen were contacted by phone and invited to participate in the project. They were paid a small honorarium for their time to respond to a set of questions. The intent was to get recommendations for study sites in 2 – 4 areas. Specifically, at least one site inside Western Gulf of Maine Permanent Closure Area, and another located in another region. Biologists met with the fishermen, either individually, or in groups to discuss their answers and review maps. Fishermen were asked to fill out a sheet in response to the following questions:

1. Where are the most consistent or best fishing sites you have visited?
2. What kind of gear do you use?
3. What kind of fish do you catch there?
4. Do you know what the bottom type is?
5. Is this seasonal. If so what time of the year?
6. Are there different types of fishing gear used in that area or close by?
7. How many years have you fished there?
8. What are the LORAN or GPS readings for the site (center of site will do)?
9. What is the approximate size of the area?
10. Do you have any suggestions as to why the area is so productive?

To the extent possible, information from these interviews was compiled in a database suitable for import to ArcView GIS. Figure 2.2 depicts the distribution of data obtained from these fishermen superimposed on GIS information from other sources. Based on the data provided, two sites were chosen. There was a clear consensus among a variety of fishing gear types that the area known as Pigeon Hill or Sanctuary Hill was a good site for a variety of fishing methods. Gillnetters and longline fishermen fished the top and edges of the "humps" and trawlers worked the flat bottom around the edges and the channel in between Pigeon Hills and Sanctuary Hill. The western boundary of the Gulf of Maine Permanent Closure Area runs through western Pigeon Hill so it was

FIGURE 2.2

SUMMARY OF GIS INFORMATION USED TO SELECT STUDY SITES



possible to delineate an area encompassing Pigeon Hills within the closed area and extending west beyond the boundary line to an area open to fishing.

There was no clear consensus in the selection of an alternate site. Suggestions included a variety of locations on Stellwagen Bank, Tillies Bank and further offshore. The final choice was influenced by depth limitations for the geoswath gear, and distance from shore, since the work was to be completed from relatively small vessels. The site consisted of a narrow rectangle from Long Bank, just inside the southwestern corner of the Stellwagen National Marine Sanctuary across to an area of rocky bottom just northeast of Scituate. While the Stellwagen Sanctuary is not closed to fishing, this site provided a transect across the boundary of the Sanctuary.

2.3 DESCRIPTIONS OF SELECTED SURVEY SITES

Two survey sites were selected based on evaluation of the data described above. A northern site proximal to Jeffrey's ledge was selected based largely on fishermen's interviews, strong bathymetric relief and intersection with the Closed Area. This site encompasses East Pigeon Hill and West Pigeon Hill, named by Valentine et al. (2001a), the southwestern slope of Sanctuary Hill, and a deep trench which separates these features (Pigeon Basin). Figure 2.3a depicts the boundary of the selected site, hereafter referred to as the Pigeon Hills site, using the USGS multibeam bathymetric data relief map as a background later.

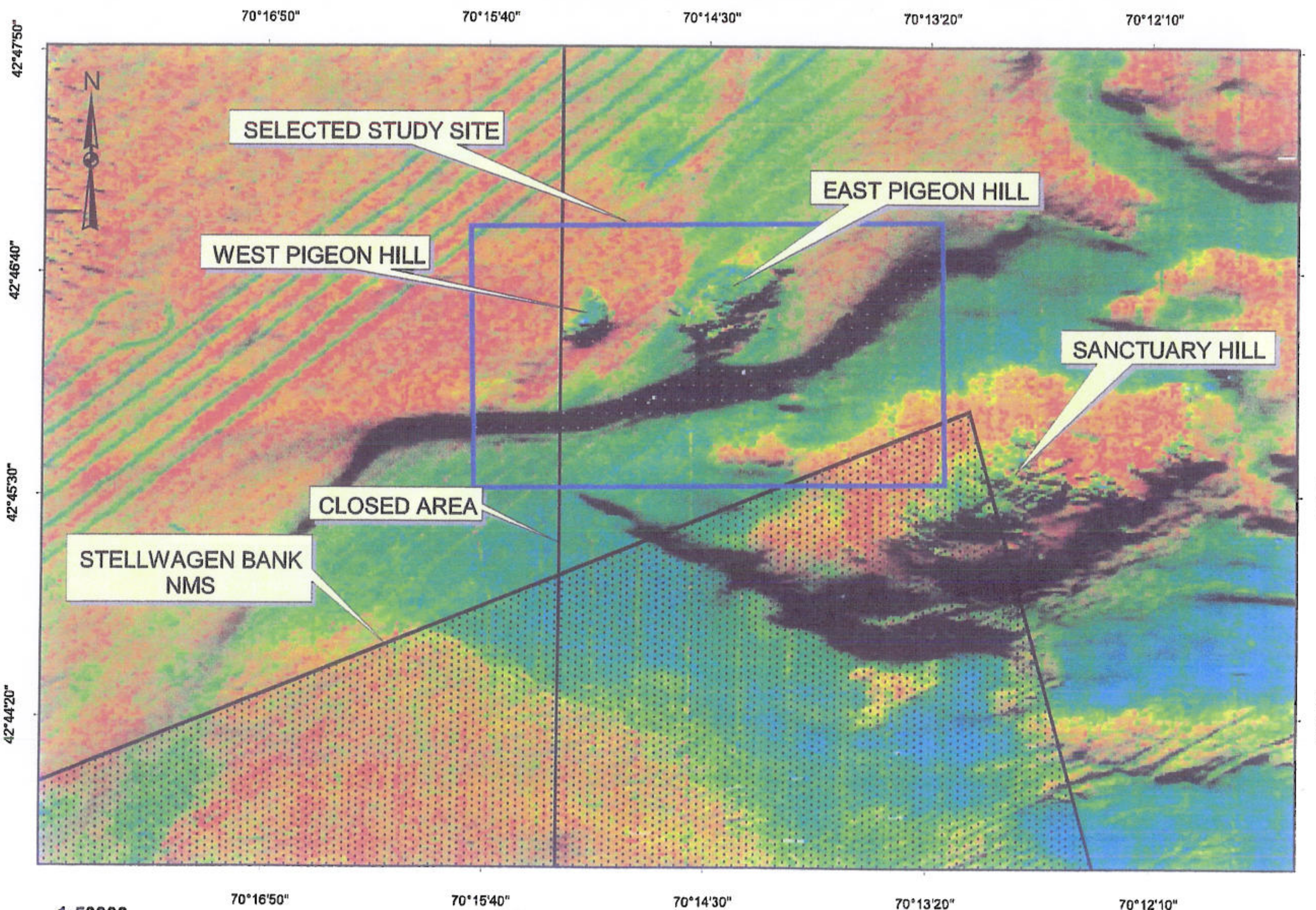
Based on USGS multibeam data, Valentine et al. (1999b) describe the Pigeon Hills and Sanctuary Hill as bedrock outcrops surrounded by sand and gravel. The dominant substrate of the bank surrounding the hills is characterized as gravel. A narrow band of sand was identified extending to the north of East Pigeon Hill.

A southern survey area partially within the boundary of the Stellwagen NMS was selected based on interview data and habitat diversity suggested by the USGS multibeam data set. The boundary of this site is depicted on Figure 2.3b using the USGS multibeam bathymetric data relief map as a background later. The Site includes the western portion of Long Bank, named by Valentine et al. (2001a) a wide area of low relief identified as a productive bottom fishing resource and the eastern portion of an unnamed bank at the western limit of the site.

Valentine et al. (1999c) describe the western bank as possessing a dominant gravel substrate, with elongated boulder piles and ridges thought to be eskers and end moraines, sometimes covered with a thin veneer of fine sediment. The basin between the banks is characterized as possessing a muddy sand to sandy mud substrate.

FIGURE 2.3A

PIGEON HILL SURVEY AREA



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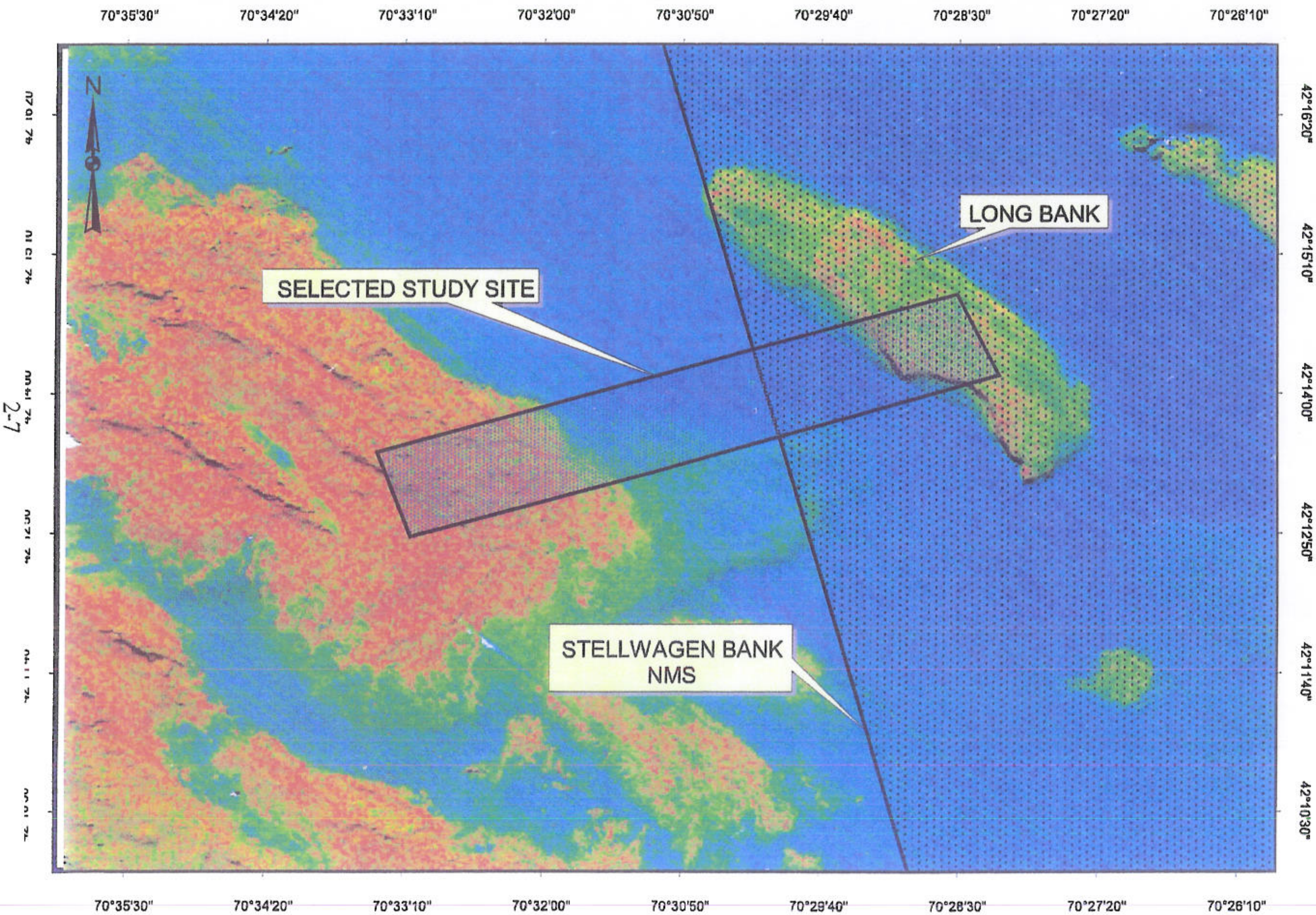
Pseudo-color multibeam background layer developed by USGS.
Open File Report 99-363

FIGURE 2.3B

SCITUATE / LONG BANK SURVEY AREA



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Pseudo-color multibeam background layer developed by USGS.
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3 INVESTIGATION METHODS

3.1 VESSEL OPERATIONS

Vessel support for the swath bathymetric, side-scan sonar, and underwater video operations was provided by the 62 ft inshore fishing dragger/research vessel *Christopher Andrew* based in Scituate, MA, the 42 ft lobster/survey vessel *Shanna Rose* based in Hull, MA, the 78 ft offshore fishing dragger *Lady Jane* and the 40 ft inshore fishing dragger *Ocean Reporter* based in Gloucester, MA. Photos of these vessels are provided below.

F/V *Christopher Andrew*

F/V *Shanna Rose*

F/V *Lady Jane*

F/V *Ocean Reporter*

The captains of these vessels Frank Mirarchi, Josh Goodwin, Russell Sherman, and Bill Lee have participated in CR's oceanographic technician training seminars and have extensive experience on past cooperative research projects. Both the *Christopher Andrew* and the *Shanna Rose* are outfitted with stern-mounted 20 ft high hydraulic A-frames, winch mounts, and hydraulic lines to accommodate a hydraulic oceanographic winch used to support both the side-scan sonar and video sled operations. All the vessels have built in benches, transducer booms, antennae mounts and 110 volt power for the survey electronics.

3.2 NAVIGATION

Navigation for the survey operations were performed by outfitting the vessels with a Trimble AGPS132 Differential Global Positioning System (DGPS) accurate to within 1 meter horizontally. The DGPS system was interfaced to a laptop computer loaded with HYPACK® Windows PC-based hydrographic survey software developed by HYPACK, Inc. (formerly Coastal Oceanographics, Inc.). The HYPACK® software displayed real-time vessel position relative to planned survey transects using an electronic nautical chart of the study area as a background. HYPACK was used to record position information for video drifts and most water profiling events, simplifying incorporation of these data into the project GIS database.

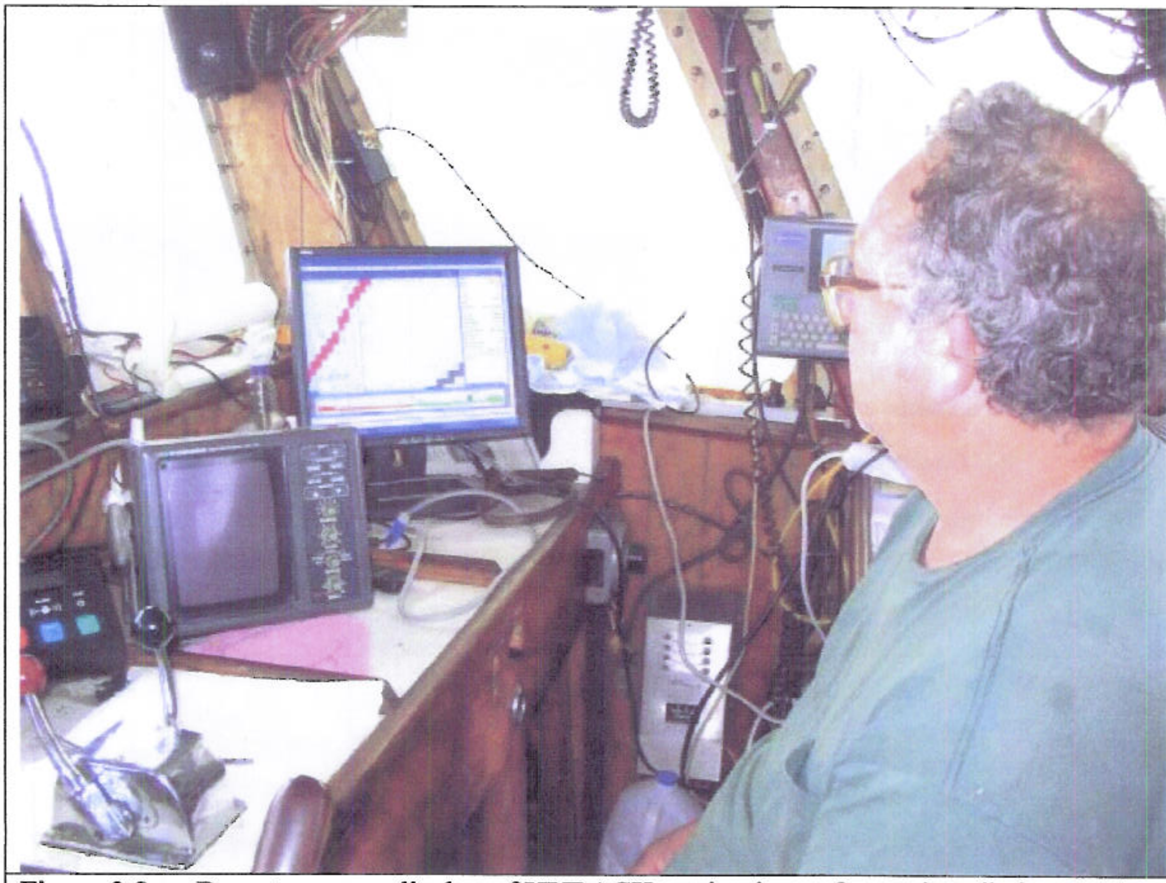


Figure 3.2a – Remote screen display of HYPACK navigation software installed on bridge of F/V Lady Jane.

3.3 SWATH BATHYMETRY

3.3.1 SYSTEM DESCRIPTION

The bathymetric survey was conducted using swath (interferometric) survey methods. The selected survey instrument was the 125-kHz GeoAcoustics, Inc. GeoSwath interferometric bathymetry system. The system has proven effective in NOAA shallow water trials, with resolution and detection capabilities similar to those of conventional beam-forming multibeam sonar systems (Gostnell, 2005). In shallow water tests, the GeoSwath has also been shown to be capable of surveying over a substantially wider swath than conventional multibeam systems (Gostnell, 2005). Team members for this investigation suggested use of the GeoSwath for bathymetric data acquisition based on the ease of system deployment on vessels of opportunity and the low lease costs relative to conventional beam forming systems.

The GeoSwath consists of port and starboard arrays of transducers (staves) mounted on a "V" plate angled 45-degrees from horizontal (see Figure 3.3a below). The GeoSwath system includes an integral Motion Reference Unit (MRU), altimeter and sound velocity probe, each mounted within the transducer array. Communication cables run from the transducer array to an acquisition computer. V-plate mounted instrumentation was interfaced with a precision SG Brown gyrocompass and Trimble DGPS. Data acquisition was conducted using a proprietary GeoAcoustics product, the Swath32 software suite.

Figure 3.3a - GeoSwath V-Plate transducer array.

Each GeoSwath transducer array includes one transmit stave and four receive staves. Each transmit stave emits discreet (16μS to 1mS duration) narrow (0.9° azimuth) sonar pulses at a rate determined by the selected swath width. The transmitted pulse is conceptually equivalent to the signal of a conventional side scan sonar system. The GeoSwath calculates and records depths by measuring amplitude and phase differences of the returning sonar signal between receive staves. These measurements are made at micro-second level intervals, and are used to determine the angle and range of the insonified seafloor. The high sample rate generates depth measurements with approximately 12-mm across-track spacing (i.e., perpendicular to the vessel course). Thus, GeoSwath across-track sounding density is approximately 8,300 for a 100-meter wide swath. Along-track data density is determined by the ping (transmit) rate, which is dependant upon the selected swath width and vessel speed. At a swath width of 300-meters (150m to port, 150m to starboard), the transmit rate would be 5 pings per second. At a typical survey vessel speed of 5 kt (2.5 m/s), along track ping density would be approximately 50-cm. The GeoSwath system also generates side-scan sonar imagery, facilitating bottom classification and target identification.

The published design specifications for the GeoSwath system indicated that depths at the selected survey sites were within acceptable limits for the 125-kHz system (rated depth reported as 200 meters, dependant upon water column characteristics and bottom composition.

3.3.2 SWATH ACQUISITION

The bathymetric survey at the Stellwagen / Long Bank (SLB) Site was conducted between July 27 and 30, 2004 aboard the F/V Christopher Andrew. The swath system was mobilized on July 26 and the survey commenced on July 27. Severe weather precluded survey activities on July 28. Based on in-situ observations of data quality and density across the swath, survey track lines spaced 100-meters apart were designed using HYPACK. Swath width was adjusted between 100m to 120m to ensure 100-percent overlap and to allow port-processing of outlying soundings observed at outer portions of the swath without compromising coverage or data quality. Figures 3.3b and 3.3c below show the GeoSwath system installed on the F/V Christopher Andrew.

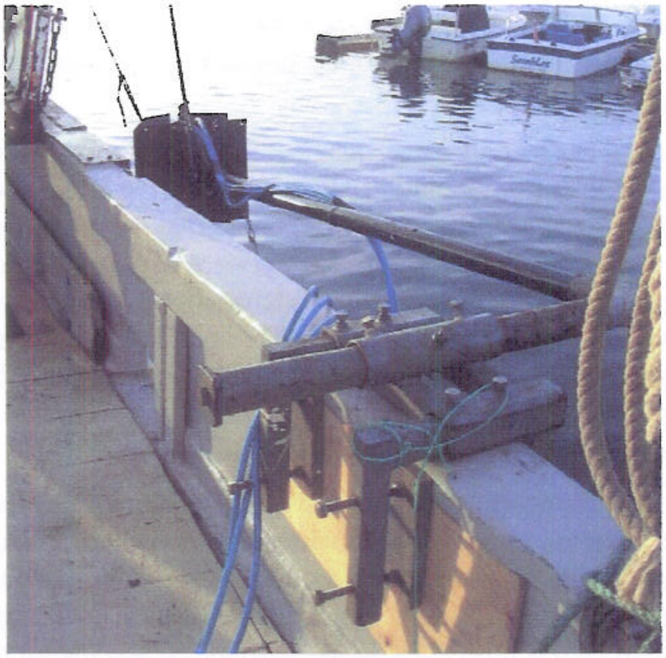


Figure 3.3b - GeoSwath transducer array mounted on adjustable boom on port side of F/V Christopher Andrew

Figure 3.3c - GeoSwath topside acquisition system (right) and towed side scan sonar acquisition system (left) installed in galley of F/V Christopher Andrew.

The bathymetric survey at the Pigeon Hill (PH) Site was conducted between August 3 and 4, 2004 aboard the F/V Lady Jane. The swath system was mobilized on August 2 and the survey commenced on August 3. Due to the long transit time from Gloucester to the survey area, the vessel remained at sea between survey days. Survey track lines spaced 80-meters apart were designed using HYPACK. Swath width was adjusted between 120m to 140m to ensure 100-percent overlap and to allow port-processing of outlying soundings observed at outer portions of the swath without compromising coverage or data quality.

The swath system relies heavily on installation-specific calibrations for accurate range/depth calculation. The boom-mounted system could not be left in a vertical deployment configuration during transit to and from the survey area. Therefore, at the SLB site, daily pre-survey and post-survey calibrations were conducted upon arrival at the site and prior to departure for port. At the PH site, dense mats of floating vegetation (likely senescent Fucus sp.,) were frequently encountered and became entangled in the GeoSwath transducer array, in two instances requiring that the transducer by lifted from it's vertical deployment for cleaning. Therefore, calibrations at the PH site were conducted pre- and post-survey and following each transducer cleaning.

Swath system calibrations are used to calculate correction coefficients for transducer and MRU orientation, gyrocompass orientation relative to the transducer array and the true vessel heading, and for acquisition system latency. Calibration coefficients are applied to correct data for vessel motion (pitch, heave and roll), heading (yaw) and latency (the delay between DGPS position solution calculation and digital recording). System calibration (commonly referred to as a "patch" test) was conducted by collecting data along three parallel track lines in opposite directions, yielding overlapping port/starboard data to be compared. A final pass along one of these lines is surveyed at a higher than normal speed to allow calculation of latency.

In addition to calibration of the GeoSwath system for the parameters listed above, accurate seabed measurements require adjustments for changes in sound velocity within the water column associated with temperature and salinity gradients. Haloclines and thermoclines can cause refraction of the transmitted sonar signal and refraction of the returning echo. Strong refraction can result in substantial water column "noise" in the sonar data, reducing seabed data density. Strong water column stratification and resulting refraction can also adversely affect the accuracy of range/depth calculations, particularly in outer portions of the sonar swath. The potential interference from refraction is compounded in survey areas where water column structure varies over relatively short periods of time due to tide and current, and space due to thermocline compression.

In order to minimize the effects of sound velocity variation on the quality of swath data, water column profiles were conducted at each survey area as frequently as practically feasible without substantially hampering the progress of these time and budget limited surveys. Profiles were conducted using a Seabird Electronics, Inc. SBE-19 CTD. Sound velocity was calculated at 3-meter intervals based on measured temperature and salinity using the Chen-Millero equation. At the SLB site, 16 CTD water profiles were conducted during the bathymetric survey. At the PH site, 10 CTD water profiles were conducted during the bathymetric survey.

3.3.3 SWATH PROCESSING

Components of bathymetric data processing included calculation and application of calibration coefficients described in Section 3.3.2, correction of raw data for local tidal conditions, corrections for vertical and spatial variations of the speed of sound in water, and removal of outlying data points. All swath data processing was conducted using proprietary Geoacoustics GS32 software. The software was protected by a Dongle key provided on lease from Seatronics, Inc. Figure 3.3d below depicts a typical GeoSwath processing window for data collected at the SLB site.

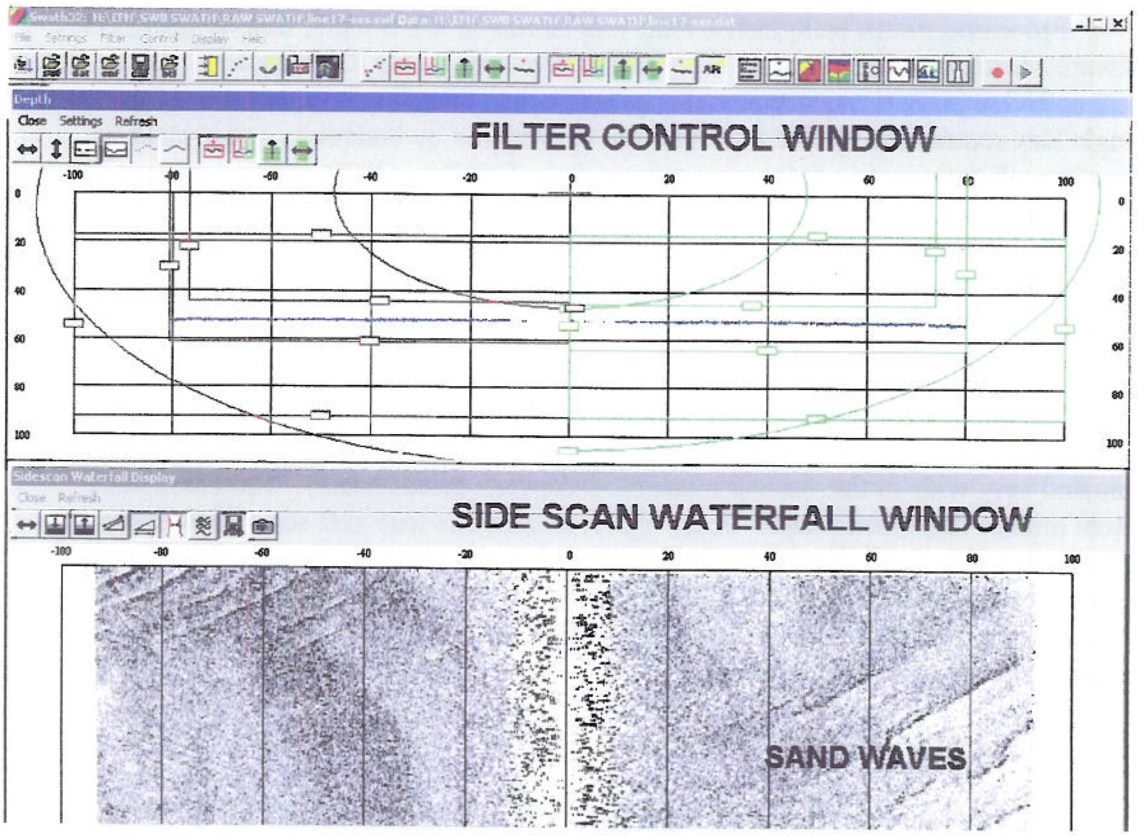


Figure 3.3d - GS32 processing window depicting filters designed to remove outlying bathymetric soundings with simultaneous generation of side scan sonar data.

Calibration coefficients were calculated for each patch test using GeoSwath software and applied to the corresponding portion of the data set. Correction of tidal fluctuations for offshore areas is an aspect of processing which introduces substantial potential error to the data. In order to minimize potential errors associated with these corrections, we contacted Mr. Cary Wong, the Hydro Planning Team Leader at NOAA's Center for Operational Oceanographic Products and Services (COOPS). Mr. Wong provided an offshore tidal zoning model for each of the survey areas. These models allowed us to process bathymetric data using tide data from the NOS water level station in Boston, MA (ID# 8443970) after application of site-specific time and height corrections.

An image depicting the tide model is included in Appendix B. Bathymetric data were corrected to depth below Mean Lower Low Water (MLLW).

The swath system calculated water depths based on the travel time of acoustic signals in water and therefore required accurate measurements of the speed of sound in water, which in coastal waters is primarily dependent on water salinity and temperature. Sound velocity and refraction (i.e., ray bending) corrections to soundings were made within the GeoAcoustics, Inc. GS32® software program during bathymetric data processing using sound velocity profiles collected during the surveys (see Section 3.3.2). Note that substantial water column noise and refraction were observed in data sets for both survey areas, and was particularly sever at the PH site.

Processed swath bathymetric data was binned to a 1.0-meter density using GS32 software. Data were projected to UTM Zone 19 North, NAD 83, in meters. Although the GS32 software permits many types of impressive data visualizations, our use of the Dongle Key required to enable this software was limited by budgetary constraints. Therefore, all bathymetric data was exported from GS32 in ASCII space-delimited XYZ text format and in Golden Software, Inc. GRD format. This allowed intensive analysis using both ESRI GIS software (ArcView 3.2a and ArcMap 9.0) and Golden Software's Surfer® 8.0. Binned ASCII data was further processed to minimize data artifacts associated with refraction, vessel motion and tidal corrections. Grids of various densities (2 m to 10 m) were created from the data and used to create georeferenced maps.

As previously mentioned, the GeoSwath sonar signal is essentially equivalent to a conventional side scan sonar signal, and is very narrow in the horizontal (along track) plane and very wide in the vertical plane (150-degrees across track). The GeoSwath system utilizes this characteristic of the signal to generate true side scan sonar imagery. During our processing of bathymetric data, we also extracted GeoSwath side scan data in the proprietary Geoacoustics SWP data format (see Figure 3.3d above). Swath side scan data were exported from GS32 software in ASCII space-delimited XYZ text format and in Golden Software, Inc. GRD format.

3.4 TOWED SIDE SCAN SONAR

For these surveys, the factor limiting GeoSwath resolution was the ping rate determined by the required range setting (see Section 3.3.1). The maximum hypothetical along track resolution for the swath system was 0.5-m before processing, with a final bin density of 1.0-m. The ability of the swath side scan sonar data to discriminate bottom features was further limited by the high grazing angle (i.e., low angle of incidence) of the sonar signal relative to the seafloor. In order to allow more detailed discrimination of bottom characteristics, surveys of each site were conducted using a towed side scan sonar system and a narrower range setting than the swath system. In addition to greater resolution resulting from a higher ping rate, a distinct advantage of the towed system was an ability to decrease the grazing angle (i.e., increase the signal angle of incidence) by lowering the transducer array (towfish) lower to the seafloor.

3.4.1 ACQUISITION

Side scan sonar survey operations were performed at the Stellwagen / Long Bank Site on July 30, 2004. Side scan sonar operations at the Pigeon Hills site were conducted October 7, 2004. The purpose of the side-scan surveys was to gather more detailed information on the character of the bottom substrate. Surveys were preformed with an Edgetech 272 TD towfish and Chesapeake Technology, Inc. SonarWiz acquisition software. The side-scan system was operated at a 100 m range scale and 100 kHz frequency, and the side-scan towfish was towed as near to the bottom as possible given cable limitations. Operations were conducted from the 62-ft F/V *Christopher Andrew* captained by owner Frank Mirarchi. The *Christopher Andrew* was outfitted with a hydraulic winch with a 200 m length of multi conductor coax cable and a slip ring assembly that could support both the side-scan and underwater video sled operations (Section 3.6.1). The scientific crew responsible for side-scan operations was John Ryther, Jr. and Christopher Wright.

3.4.2 SIDE SCAN SONAR PROCESSING

Raw side-scan sonar data were processed to correct for towfish layback, adjust for signal attenuation related to swath width, and to georeference sonar imagery (i.e., project the sonar data into real-space coordinates). First, water column portions of the acoustic returns were removed through review and processing of each survey transect. Raw data were then corrected by calculating and applying accurate layback and catenary coefficients to each of the data files. Data processing also included adjustments for variations of the sonar beam angle of incidence relative to the seafloor (Beam Angle Corrections) and signal attenuation with distance (Time Varied Gain Corrections).

Side-scan sonar data were processed using Chesapeake Technology, Inc.'s SonarWeb and SonarWizMAP software. Once corrected, data from each survey lane were merged to create a single georeferenced mosaic of the survey area (in JPG format) with a resolution of 0.20-meters per pixel. Data were saved in several forms including; georeferenced JPG files; high-resolution annotated "waterfall" imagery (uncorrected raw data) of each survey lane; and navigation overview plots. Also, a set of HTML files for the project was created, allowing Web-browser (i.e., Internet Explorer or Netscape) access to all survey data and imagery. Georeferenced sonar data were incorporated in a GIS database for comparison with other data.

3.5 SUB-BOTTOM PROFILING

The bathymetric and side scan sonar data provide detailed information regarding the surficial composition of the seabed. However, because of their relatively high frequency signals, these technologies do not penetrate the seabed and do not provide information regarding depositional characteristics. Therefore, a cursory inspection of each site was conducted using a low frequency sub-bottom profiling system. The goal of these inspections was to provide insight into the geological and depositional characteristics of the seabed by documenting sub surface sediment strata and underlying parent material.

3.5.1 SUB-BOTTOM ACQUISITION

Sub-bottom profiling inspection of the Pigeon Hills and Stellwagen / Long Bank Sites were conducted aboard the F/V Shanna Rose in March, 2005. The selected profiling system was the SyQwest 10-kHz Stratabox. Data were recorded during some of the video drifts (Section 3.6.1) and by navigating along transects which bisected each of the sites. Data were recorded using proprietary StrataBox software.

3.5.2 PROCESSING

Sub-bottom profile data were processed using Chesapeake Technology's SonarWeb software. Appropriate adjustments to TVG were made during processing. Sub-bottom profiles were exported in JPG format with accompanying HTML-navigable indices.

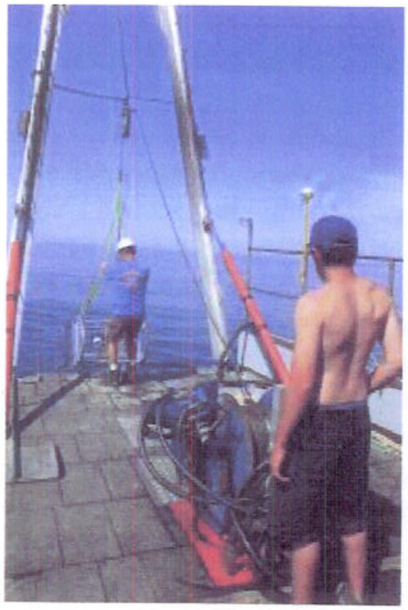
3.6 VIDEO SLED METHODS

3.6.1 CR ENVIRONMENTAL UNDERWATER VIDEO SLED OPERATIONS

Spring and fall underwater video surveys were performed at both the Pigeon Hills and Stellwagen/Long Bank study sites. In a two-day period at each area, a total of (17) 15-30 minute underwater video drifts were accomplished at each site. During the fall surveys, the flat mud/sand and cobble bottoms were targeted, and on the spring surveys, the boulder and rock ledge bottoms were targeted.

CR performed the underwater video survey with a custom designed towed video sled system. The system consists of a lightweight aluminum frame, Deep Sea Power and Light high-resolution low light color camera, and two wide-angle 250-watt lights with a variable output control. The system also uses an Outland Technologies' navigation overlay system that permits the display and recording of latitude and longitude with the video data. Data was displayed on a high-resolution flat screen monitor and recorded on both DVD and VHS recorders.

The video sled was lowered to within a few inches of the bottom with an oceanographic winch, slip ring assembly and 200-meter length of armored cable. The hydraulic winch was equipped with a flow control valve, permitting high winch speeds during deployment and retrieval operations and fine winch control when the sled was on or near the bottom. The winch operator viewed the bottom footage on a dedicated monitor and constantly adjusted the height of the sled to achieve consistent bottom coverage and video quality. The viewing area of the video camera in this drifting mode is approximately one square meter.



Video sled deployment

Video sled components including high resolution color camera, wide-angle halogen lamps

Once the vessel was on station, the captain would monitor the current and wind and would select a starting position for the video transect. The speed of the vessel drifts varied from 0.2 to 1 knot but in most cases averaged approximately 1/2 knot. In strong currents or winds, a drogue buoy was deployed to slow down the vessel drift. If the currents were in the wrong direction, the vessel would jog in and out of gear to maintain the approximate ½ knot speed. In this manner, 100-750 meters of bottom coverage was obtained in 15-30 minutes.

The depth of the video sled was monitored on the ship's echosounder during the video sled deployment. Recording of the underwater footage and navigation data was initiated when the sled first contacted the bottom. A unique HYPACK file name was given to each video transect. A team of two biologists viewed the video data in real time and preliminary field notes were taken including species identifications, rough counts of biota, and classification of bottom habitat.

After the completion of survey operations, the video sled footage on DVD was replayed on a desktop computer and viewed on a high resolution flat screen monitor. Detailed notes on habitat types and biota were recorded at 30 second intervals for the entire 15-30 minute video transect. All organisms were counted and identified to the lowest possible taxonomic designation. Representative video screen captures of the underwater footage were created using POWERDVD software.

3.6.2 DRIFT CAMERA

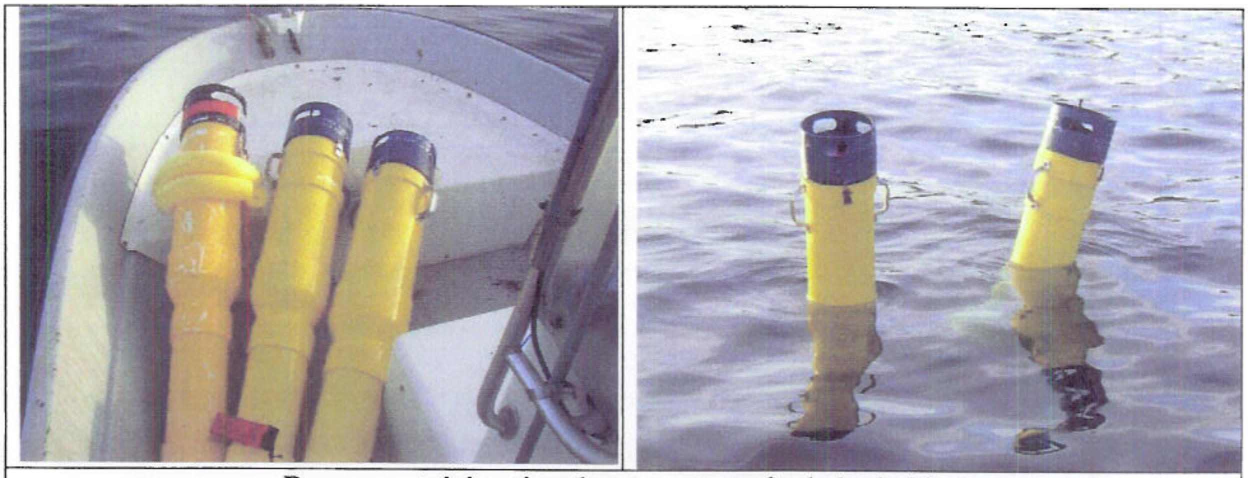
It was originally thought that the CR video sled could not be used in areas of very high relief without the possibility of damage to the gear and so a simple drop system with an inexpensive camera was deployed from the Ocean Reporter to obtain bottom video of habitat in these localities. This consisted of a low lux Sony black and white camera, in a housing made by Captain Bill Lee, lowered to the sea floor with one or two 12-volt 1152 incandescent automotive lights. The electrical cable was run through a davit into the pilothouse to a live video screen and VCR. The vessel was allowed to drift across chosen sites and the camera was manually raised and lowered to avoid contact with the sea floor or elevated objects. Start, interim, and final video locations were recorded manually. Drift length (10 – 70 minutes) depended on habitat type and the locality of fixed gear. Videos were later reviewed and minute-by-minute notes made of the type of bottom habitat, and the presence of conspicuous biota such as anemones, starfish, crabs, lobsters and fish. Because the videos were primarily taken in black and white, few organisms could be identified to species level.

3.6.3 ROV

At each site a Titan mini-ROV owned by Bill Lee was deployed at several stations in both spring and fall surveys. The unit had a tether of 100 m length and was equipped with a Sony color camera and two 50-watt 12-volt halogen lights.

3.6.4 BAITED VIDEO

A baited video recording system built by Captain Lee consisted of a frame with a video camera aimed at a bait bag and an electrical wire leading to a surface buoy which housed a time-lapse digital recorder (see below). This could be programmed to record continuously or set to other combinations such as several seconds each minute. With the time-lapse and battery capability the unit had the capacity to be in operation for 90 hours. Approximately 500 g of herring was placed in the bait bag and the gear was deployed at chosen sites for varying periods of time (2 – 24 hrs) while other survey tasks were completed.



Buoys containing time-lapse cameras for baited video

3.7 CTD

During the geoswath and sidescan surveys an SBE Seacat 19 profiler was lowered to the sea floor to obtain data on the structure of the water column. Parameters measured were temperature, salinity and oxygen. A flourometer was added to the instrument during additional surveys conducted in the fall and the spring. In the laboratory data was downloaded and summarized using Seacat software.

3.8 BENTHIC SAMPLING

3.8.1 INFAUNA

Seven stations were established across the Stellwagen/Long Bank transect starting with Station 1 on the edge of Long Bank and crossing to Station 7, just before the rocky outcrop area at the western end of the study site (Figure 3.8). Depth ranged from 55.5 meters at SB 7 to 67 m at SB 2. Three replicate benthic grab samples were collected at each site using a 0.25 m^2 Ted Young grab. The samples were sieved through a 0.5 mm mesh screen, fixed in formalin for 48 hrs and preserved in isopropyl alcohol. Benthic infauna was sorted from the resulting material under a binocular scope and identified to the lowest practical taxon. Replicate samples were also obtained from an area to the southwest called Mud Hole where a previous CRPP study on the effects of trawling was conducted (Boat Kathleen A. Mirachi Inc. and CR Environmental Inc., 2005). In that study, surveys were taken before and after trawling along two lanes in areas called "Mud Hole" and "Little Tow". One site was selected in each of two lanes of the Mud Hole site which had sediments more similar in composition to those from the study area for this project. MH2B and MH4B were stations on control lanes from the previous study and would provide comparative data.

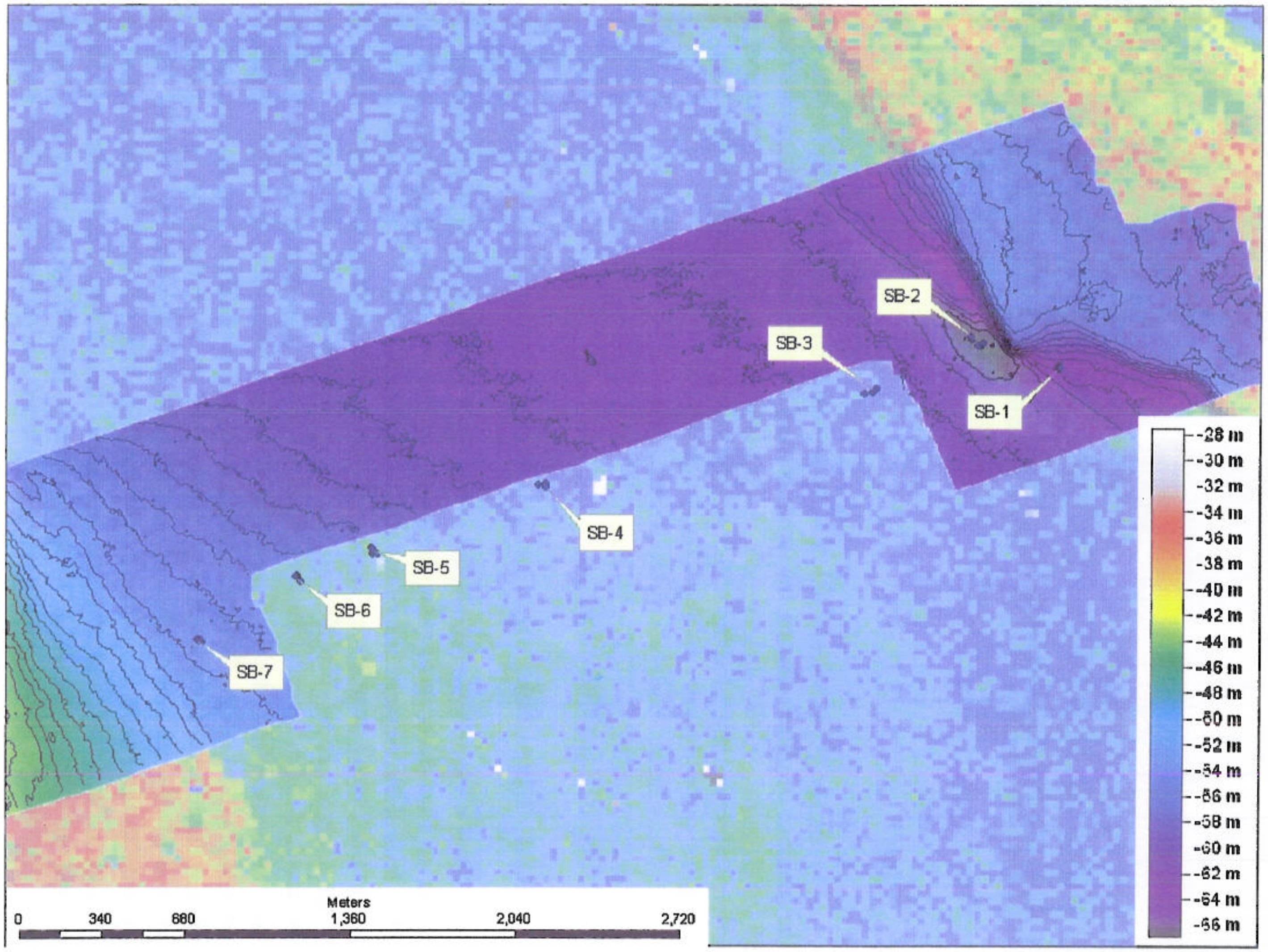


Figure 3-8. Benthic infaunal and sediment sampling sites on Stellwagen/Long Bank transect

Benthic infaunal sampling was not conducted at the Pigeon Hills site. Analysis of the available descriptions for the area suggested that the bottom type was unsuitable for grab sampling. The center of the site consisted of ledge, boulders and cobble. Bottom material in the channel in between Pigeon Hills and Sanctuary Hill was, according to boat captains, coarse, gravelly sediment – not suitable for benthic grab sampling. Some sand patches occur among the boulders on the western side of east Pigeon Hill but there was significant risk of gear damage trying to sample in these areas.

3.8.2 SEDIMENTS

Two replicate sediment samples were collected from grab samples at seven sites in the Stellwagen transect and the two sites at Mud Hole. Samples were divided into coarse and fine fractions by wet sieving through a 0.062 mm screen (4 phi). The coarse fraction was dried and sieved through a series of screens at phi intervals on a RoTap shaker. Silt/clay content was determined by pipette analysis. Size classes were expressed as a percentage dry weight.

4 RESULTS

4.1 GEOSWATH

GeoSwath bathymetric data were used to create detailed maps of bathymetry for each site. Two versions of bathymetric maps were created for each site: (1) conventional contour maps indicating depth below MLLW using 1.0-meter contour intervals and full spectrum color gradients; and (2) surface maps which utilize vertical exaggeration, color gradients and artificial "sun-illumination" to produce 3-dimensional representations of seabed topography. These surface maps aid evaluation of subtle morphological features which would be indiscernible on conventional contour maps.

GeoSwath side scan sonar data were also used to create two representations of the seafloor for each site. The first sets of representations are side scan sonar mosaics created from the ASCII delimited text files exported from GS32. These grey-scale mosaics allow wide-area differentiation of substrate characteristics and geological formations. For the second set of GeoSwath side scan sonar maps, the sonar mosaic was digitally draped over the bathymetric surface model of each site, aiding sonar interpretation by allowing consideration of sonar backscatter relative to seabed topography.

4.1.1 PIGEON HILLS SWATH DATA

Figure 4.1.1a presents a color-coded bathymetric map of the Pigeon Hills site created from the GeoSwath data. Figure 4.1.1b presents a bathymetric surface map of the Pigeon Hills site using artificial illumination to highlight seabed morphology. Figure 4.1.1c presents a side scan mosaic created from GeoSwath data, and Figure 4.1.1d presents the sonar mosaic merged with the bathymetric surface model.

The bathymetric data clearly identify each of the Pigeon Hills and the lower portion of Stellwagen Hill at the southeast limit of the survey area. Depths at the Pigeon Hills site ranged from 29.6 meters MLLW at the peak of East Pigeon Hill to 113 meters MLLW in the trench (Pigeon Basin), which bisects the site. The bathymetric data suggests that the Pigeon Hills are bedrock ledges or outcrops. Each possesses fine crevasses oriented along approximately easterly axis (see Figure 4.1.1e and 4.1.1f below). The data also suggest that a large landslide may have occurred at the southern toe of East Pigeon Hill. Data indicate a large deposit of material at the toes of the slope below this feature (see Figure 4.1.1e below).

FIGURE 4.1.1A
BATHYMETRIC MAP OF PIGEON HILLS

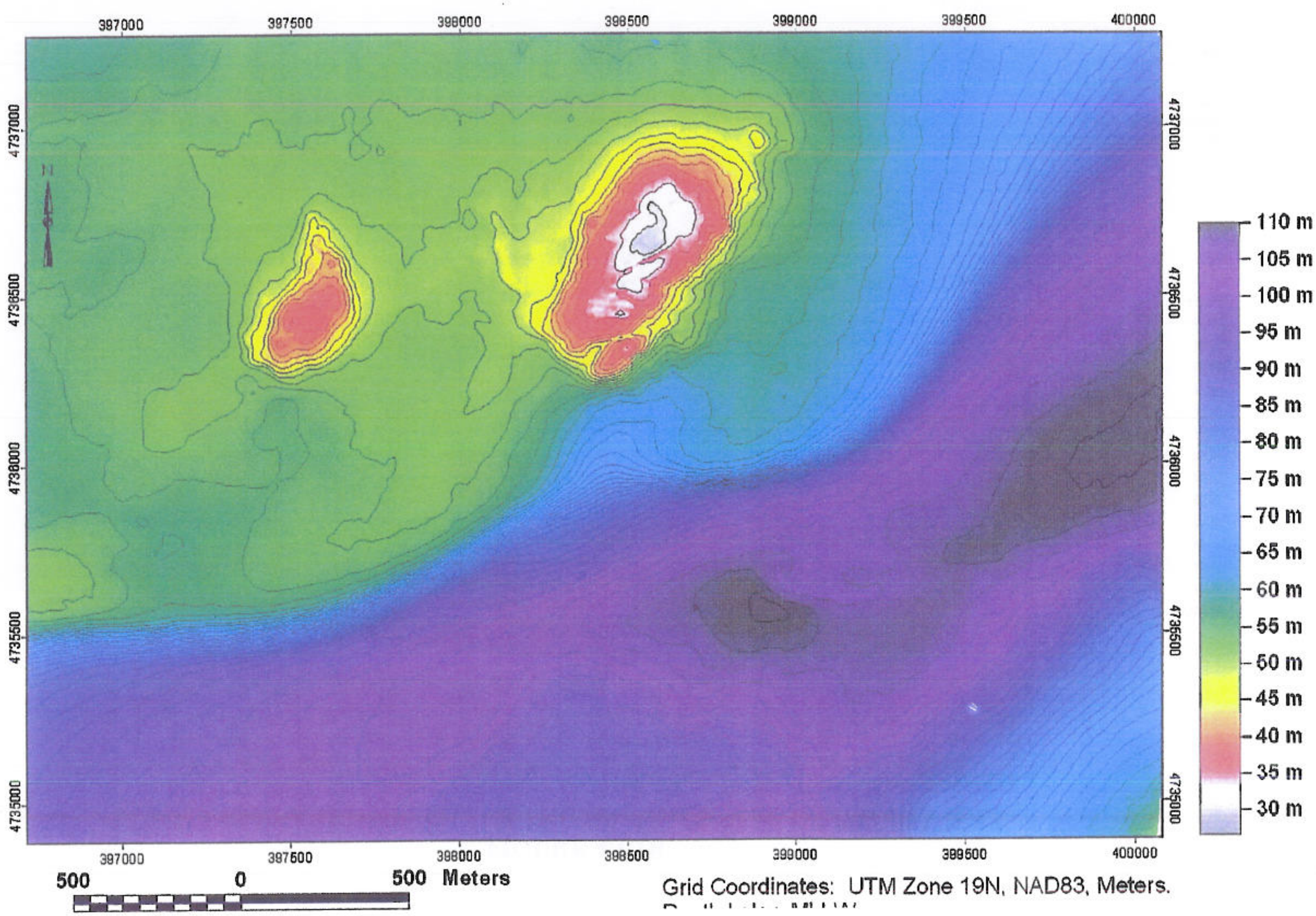


FIGURE 4.1.1B
"SUN ILLUMINATED" BATHYMETRIC SURFACE MAP OF PIGEON HILL

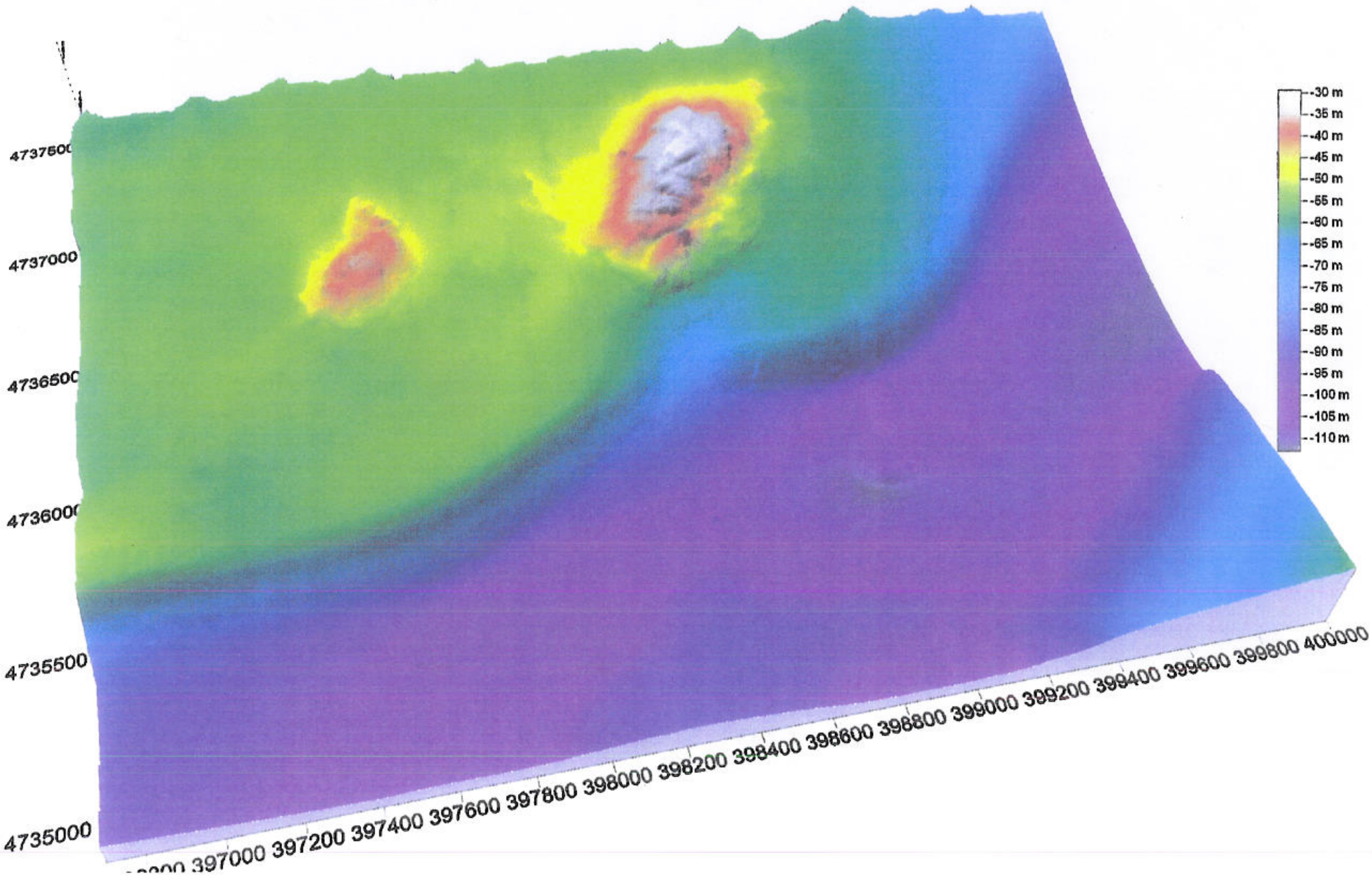


FIGURE 4.1.1C

GEOSWATH SIDE SCAN SONAR MOSAIC OF PIGEON HILL

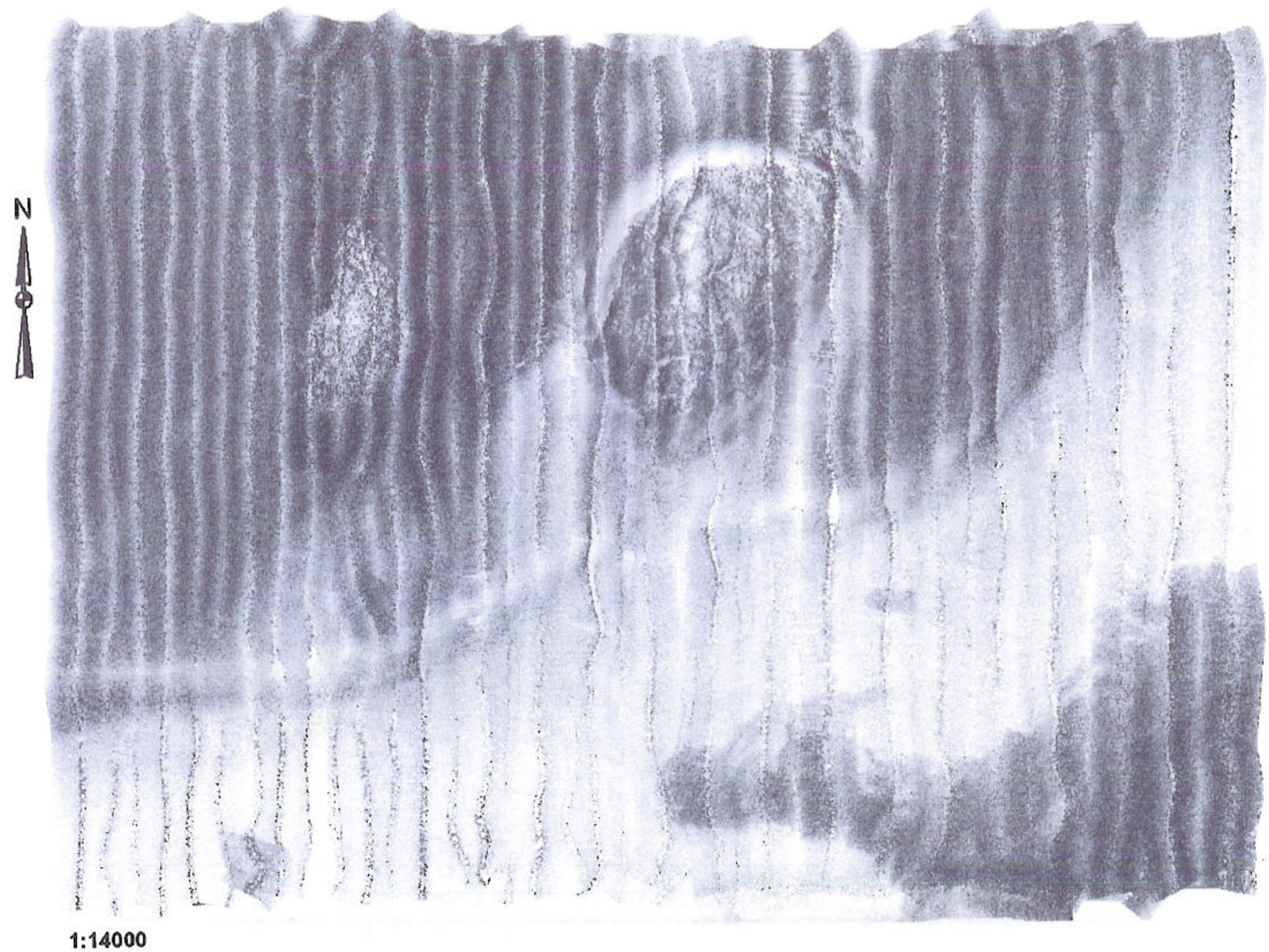
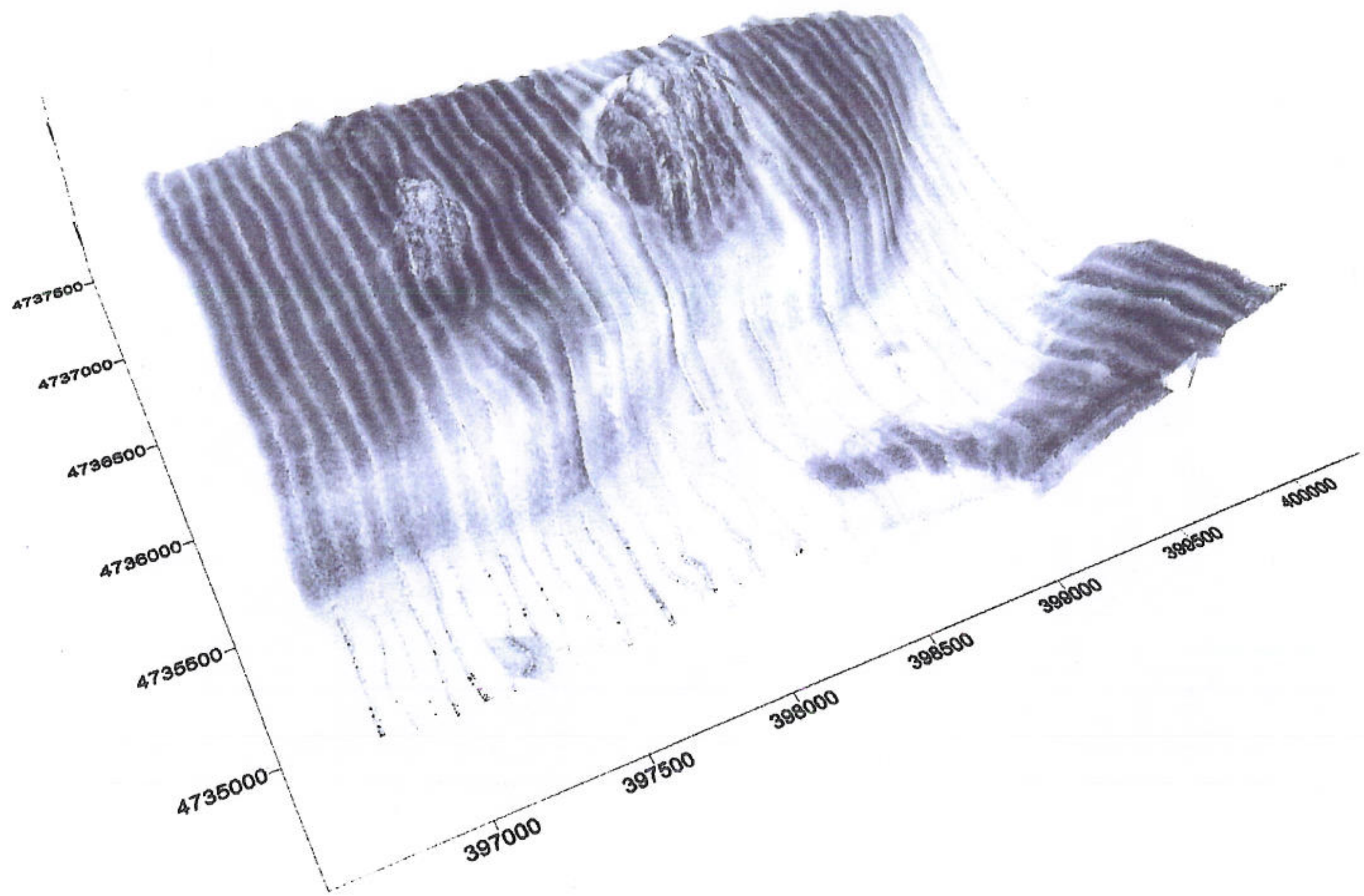


FIGURE 4.1.1D

GEOSWATH SIDE SCAN SONAR MOSAIC OF THE PIGEON HILL SURVEY AREA
MERGED WITH THE SWATH BATHYMETRIC SURFACE MODEL
10X VERTICAL EXAGERATION



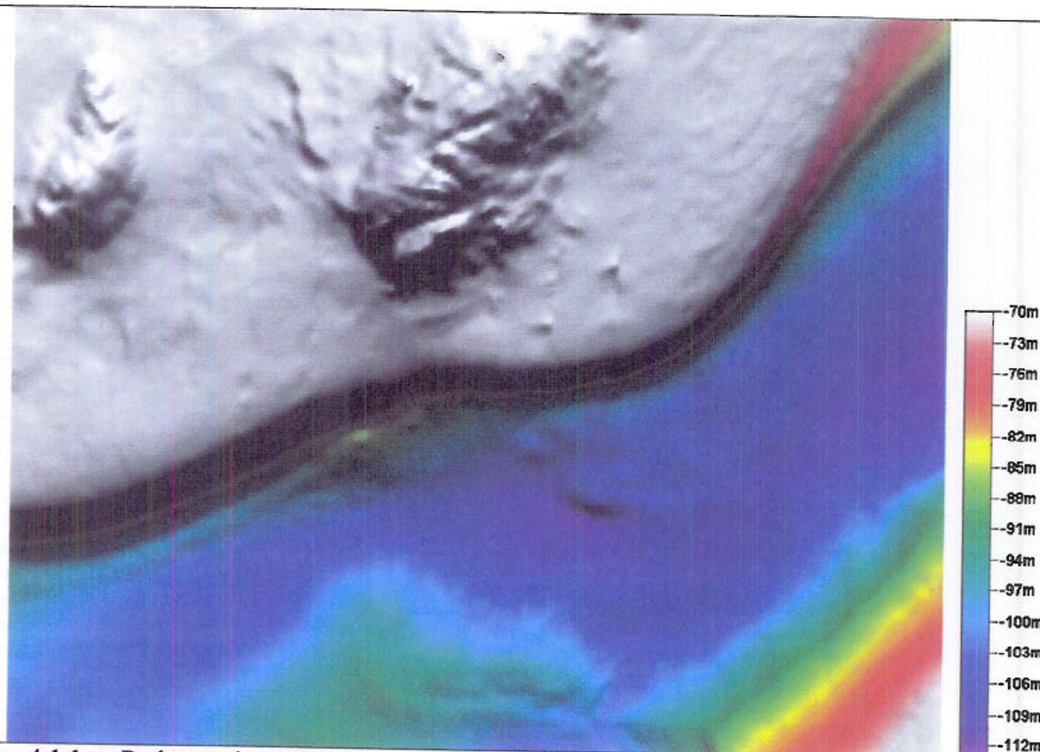


Figure 4.1.1e – Bathymetric surface map of Pigeon Hills adjusted to highlight seabed structure at the bottom of the trench. 10x vertical exaggeration.

The bathymetric surface map depicted in Figure 4.1.1e clearly shows that Pigeon Basin contains a high degree of topographic relief. The data clearly depict a sinuous ridgeline which bisects the trench between the toe of Sanctuary Hill and the Pigeon Hills "plateau" (Jeffrey's Ledge). The bathymetric relief present at the bottom of the trench suggests a coarse parent material, likely covered by a veneer of finer sediment.

Figures 4.1.1c and 4.1.1d suggest that the substrate covering the majority of the survey area is relatively coarse, likely dominated by gravel and cobble. The plateau surrounding Pigeon Hills lacks substantial bathymetric relief, with depth ranging from 55 to 60 m. Complex ravines or crevasses are shown on each of the Pigeon Hills. Swath side scan sonar data suggests that finer substrate, likely sand, is present directly south of both of the Hills and in a narrow band to the north of East Pigeon Hill, likely reflecting local near-bottom currents. Backscatter data for the bottom of the trench is characterized by low reflectivity, suggesting a silty sand substrate. Figure 4.1.1f below allows simultaneous examination of swath side scan and bathymetric data using an artificially illuminated map created by merging the two data sets.

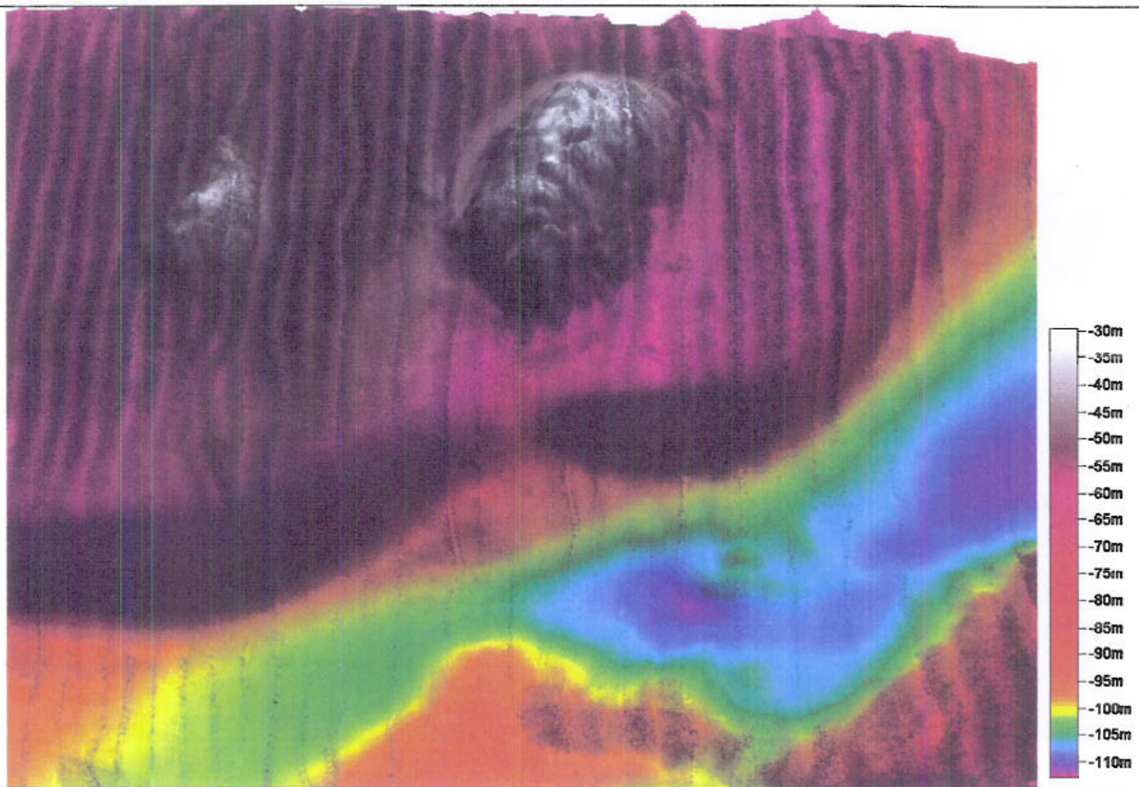


Figure 4.1.1f – Surface map of Pigeon Hills adjusted to highlight seabed structure within the Pigeon Basin trench using merged GeoSwath side scan sonar and bathymetric data (10x vertical exaggeration of a 10-m grid).

The merged GeoSwath data set shows that distinct geological formations are present in areas of row reflectivity. This supports our previous suggestion that the substrate in the trench is likely composed of a relatively thin veneer of fine sediment (e.g., sandy silt) underlain by coarse material or ledge.

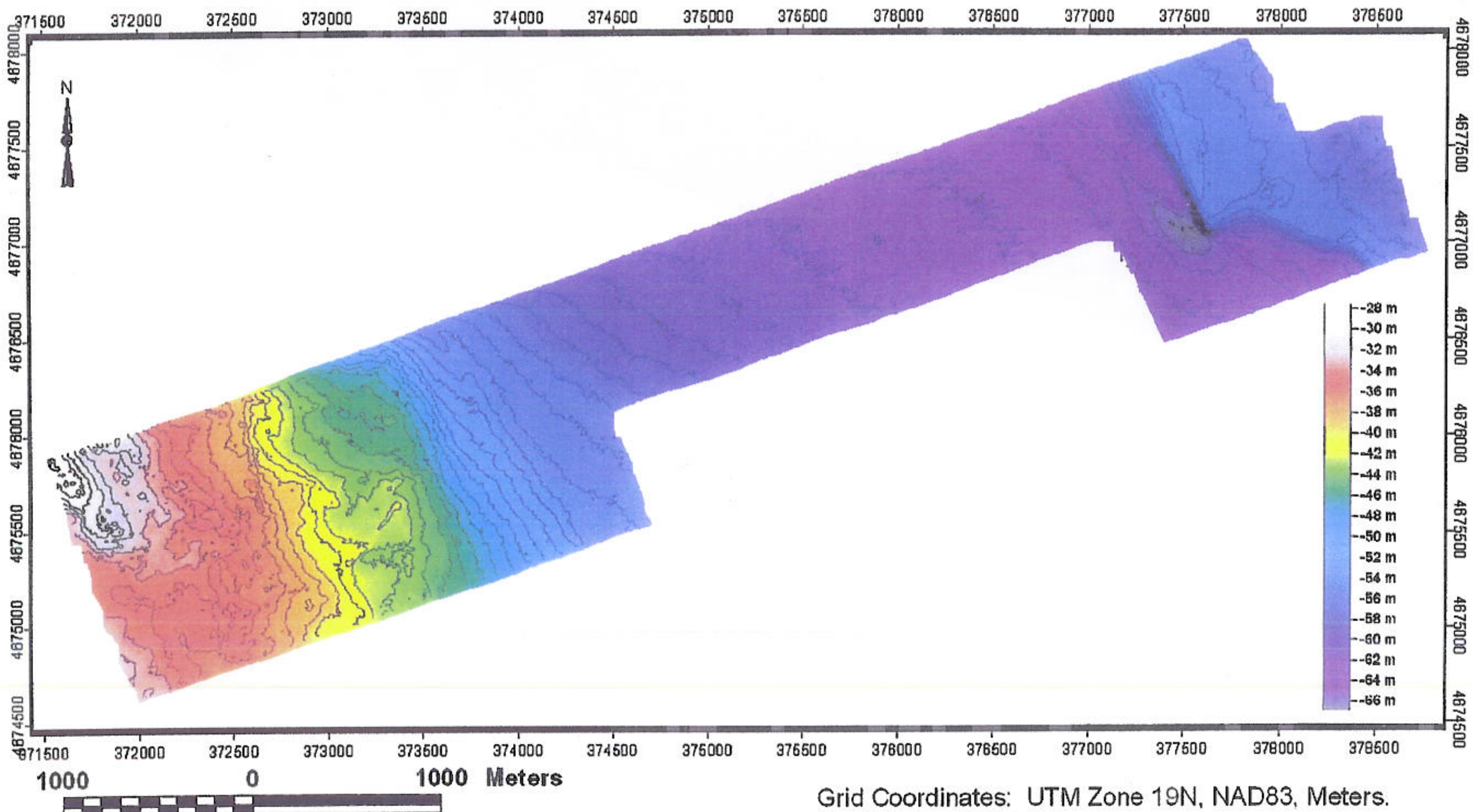
4.1.2 STELLWAGEN / LONG BANK BATHYMETRY

Figure 4.1.2a presents a color-coded bathymetric map of the Stellwagen / Long Bank site created from the GeoSwath data. Figure 4.1.2b presents a bathymetric surface map of the Stellwagen / Long Bank site using artificial illumination to highlight seabed morphology. Figure 4.1.2c presents a side scan mosaic created from GeoSwath data, and Figure 4.1.2d presents the sonar mosaic merged with the bathymetric surface model.

The bathymetric data clearly identify Long Bank at the eastern edge of the survey area and the large unnamed bank at the western limit of the survey area. These features are separated by a wide expanse of relatively smooth flat bottom. A shipwreck named the "Bronze wreck" by local fishermen is clearly visible on Figures 4.1.2a though 4.1.2d approximately 1400 meters west of Long Bank on the smooth flat seabed. Depths at the Stellwagen / Long Bank site ranged from 28 meters MLLW at the highest point of the western bank to 66 meters MLLW in a depression adjacent to Long Bank.

FIGURE 4.1.2A

BATHYMETRIC MAP OF SCITUATE / LONG BANK SURVEY AREA
1.0 METER CONTOUR INTERVAL
1.0 METER GRID INTERVAL



Grid Coordinates: UTM Zone 19N, NAD83, Meters.
Depth below MLLW

FIGURE 4.1.2B
N ILLUMINATED" BATHYMETRIC SURFACE MAP OF STELLWAGEN / LONG BANI
10X Vertical Exaggeration

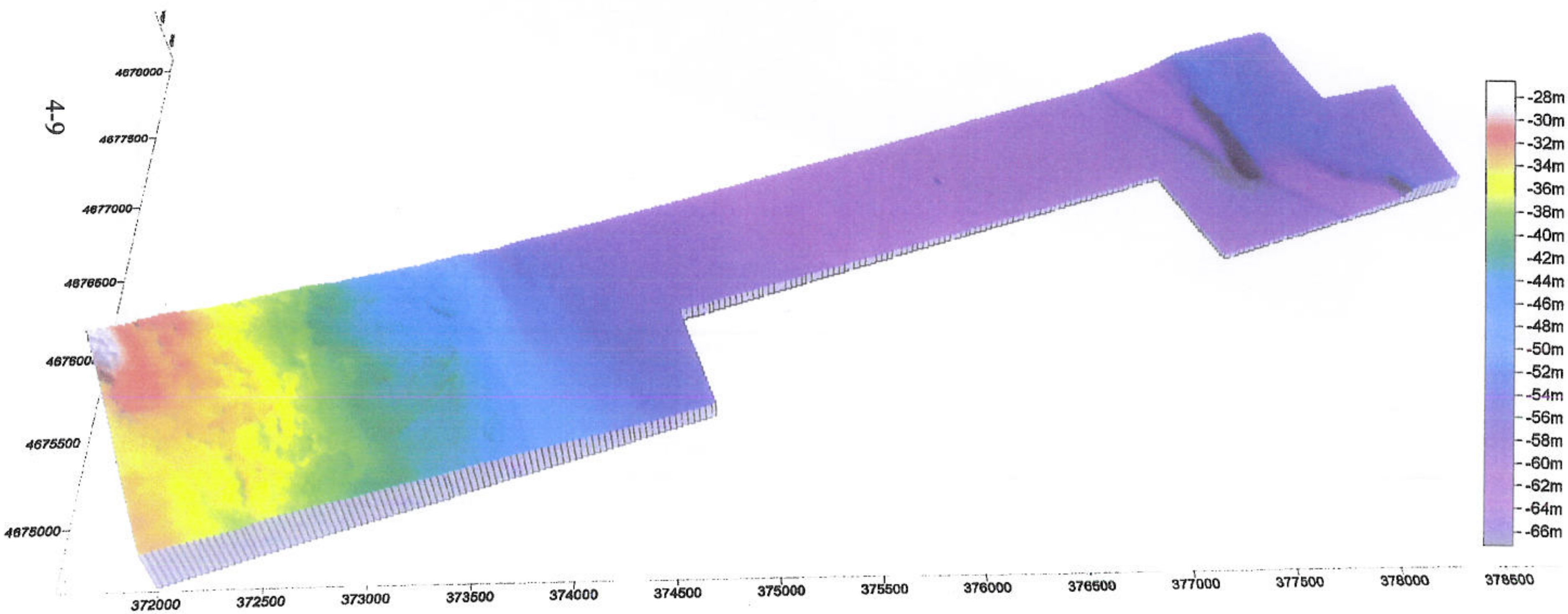


FIGURE 4.1.2C

GEOSWATH SIDE SCAN SONAR MOSAIC OF STELLWAGEN / LONG BANK SITE

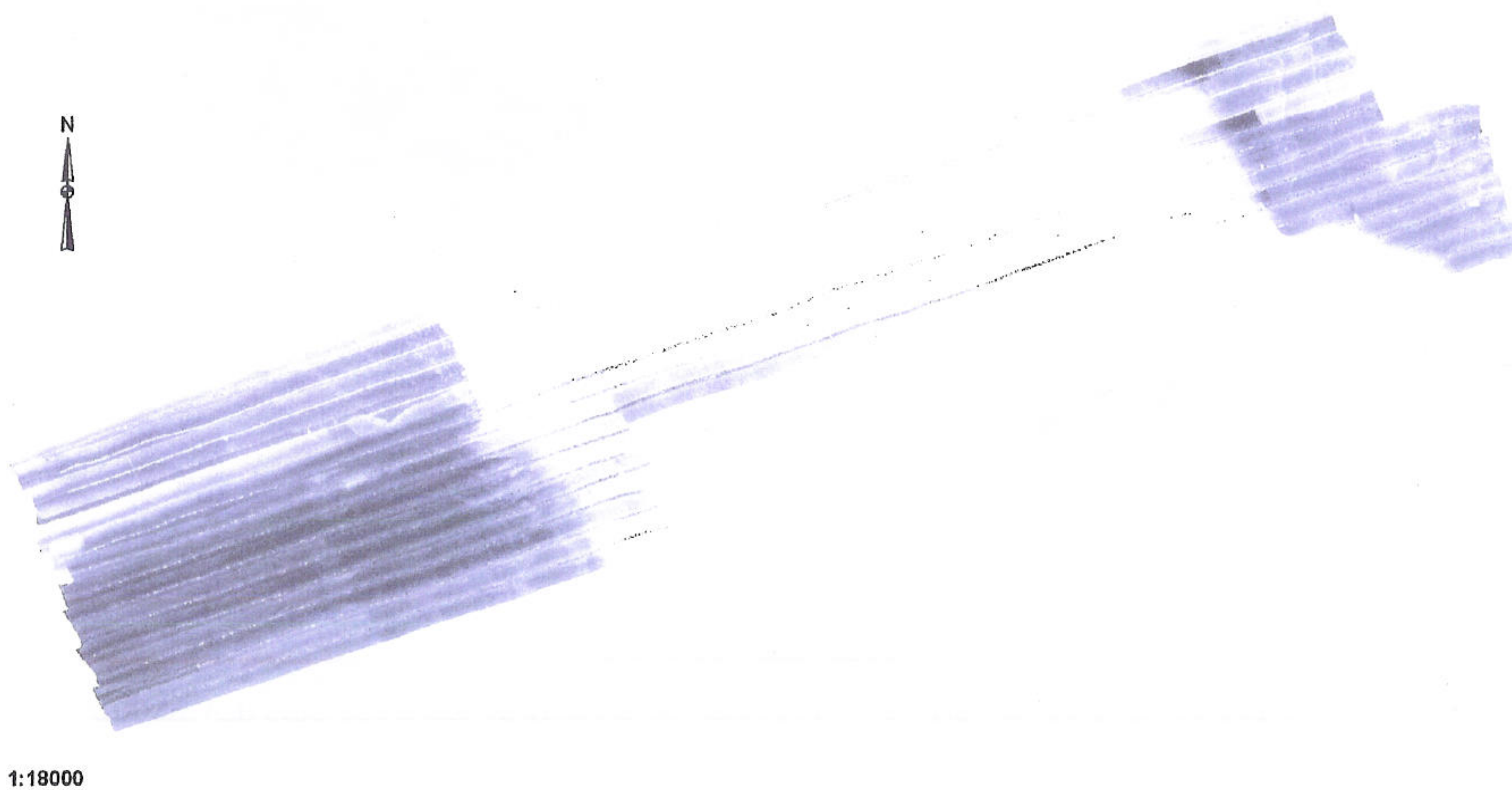
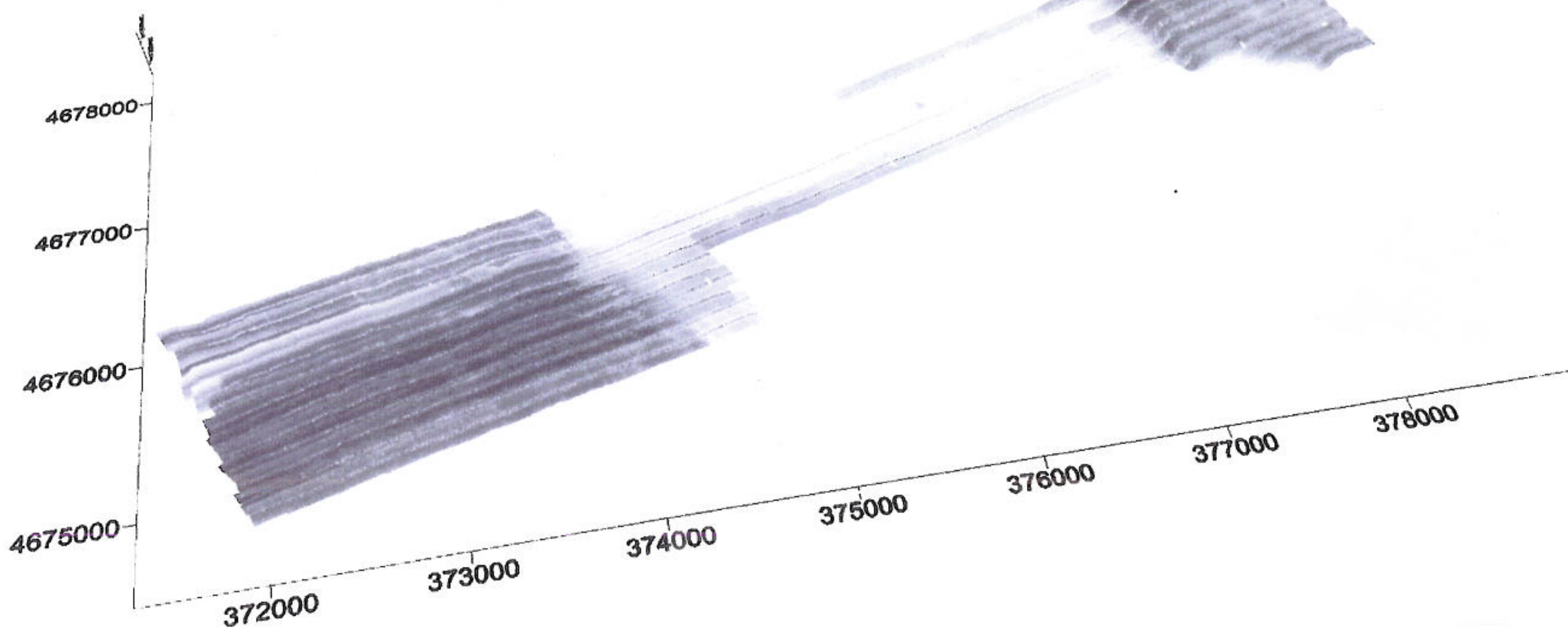


FIGURE 4.1.2D

GEOSWATH SIDE SCAN SONAR MOSAIC OF THE SCITUATE/LONG BANK SURVEY AREA
MERGED WITH THE SWATH BATHYMETRIC SURFACE MODEL
10X VERTICAL EXAGERATION



The bathymetric data shows a western bank dominated by irregular arrangements of subtle (~1 – 3 m) ridges (see Figures 4.1.2e and 4.1.2f below). The northwestern extent of the survey area has a configuration that suggests bedrock ledge. Formations along the eastern edge of this bank suggest deposits of glacial origin leading to the deeper smooth seabed, likely dominated by sand, gravel and cobbles.

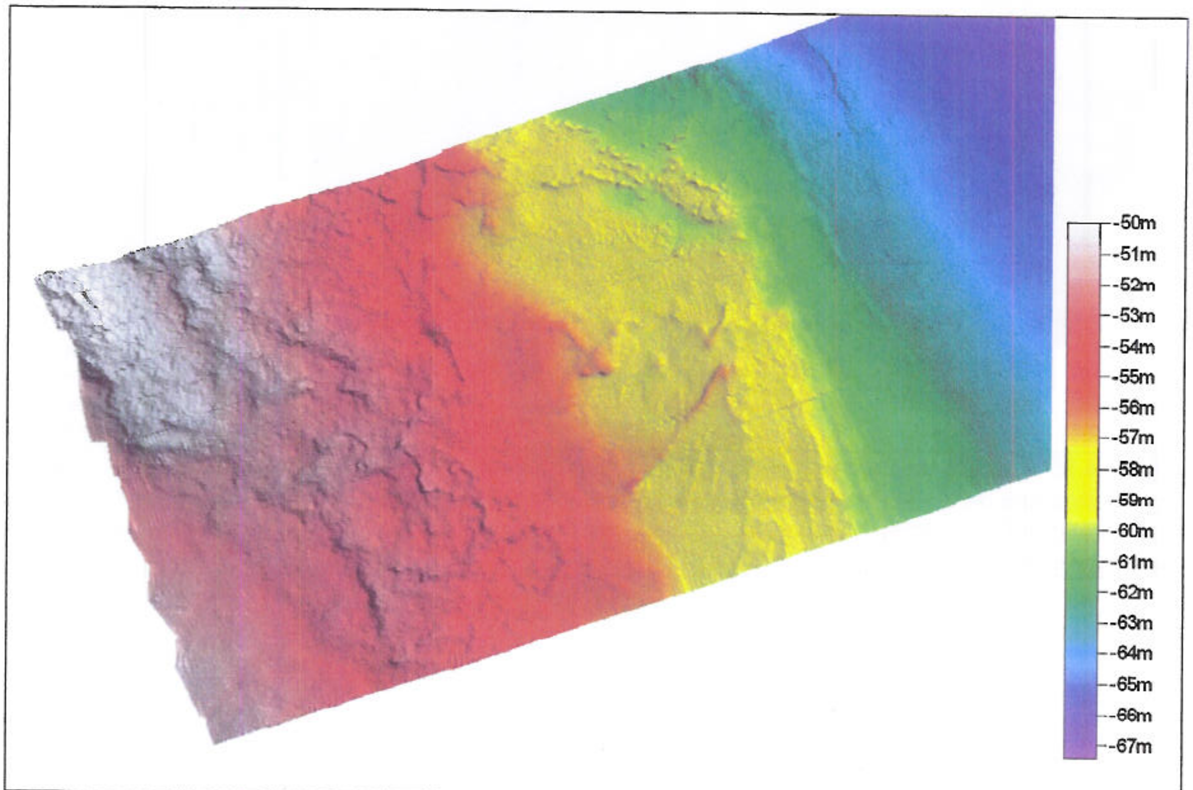


Figure 4.1.2e – Artificially illuminated bathymetric surface map of the western bank at the Stellwagen / Long Bank survey area. 1.0 m grid, 10x vertical exaggeration. Data artifacts associated with motion and tide corrections are clearly visible due to the level of exaggeration

There appears to be a relatively abrupt transition from the coarser materials which constitute the substrate of the western bank to the lower reflectivity sand substrate which dominates the central portion of the survey area (see Figure 4.1.2f below).

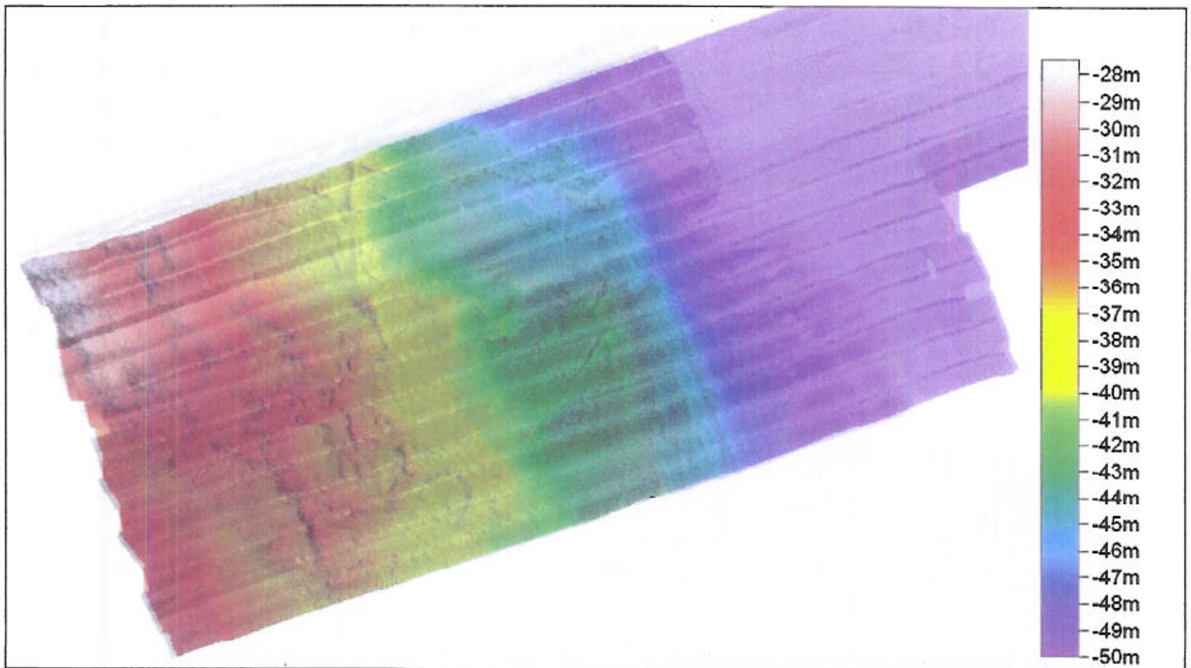


Figure 4.1f – Surface map of the western portion of the Stellwagen / Long Bank site adjusted to highlight seabed structure on the bank using merged GeoSwath side scan sonar and bathymetric data (10x vertical exaggeration of a 1m grid). Artifacts on this map are largely associated with swath side scan sonar slant range corrections.

The bathymetric data shows that Long Bank (the eastern bank) is dominated by a regular arrangement of subtle (~1 – 3 m) ridgelines with a generally northerly orientation (see Figures 4.1.2g and 4.1.2h below). These features are likely glacial deposits of coarse material ranging from gravel to cobble.

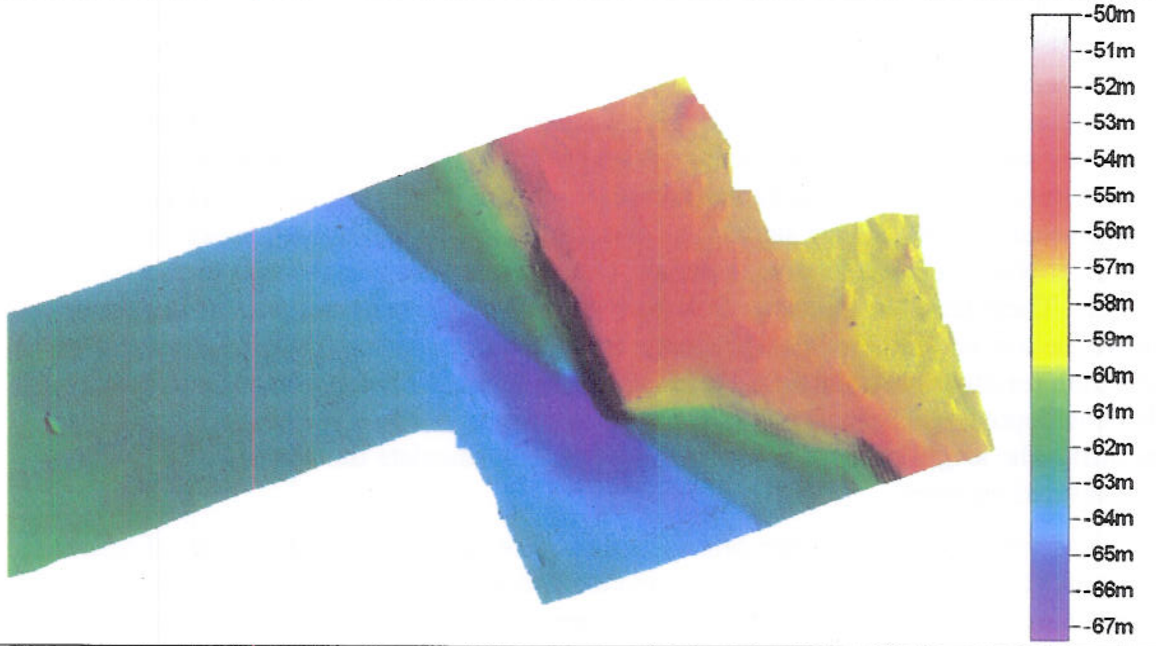


Figure 4.1.2g – Artificially illuminated bathymetric surface map of Long Bank. 1.0 m grid, 10x vertical exaggeration. Data artifacts associated with motion and tide corrections are clearly visible due to the level of exaggeration. Note wreck at western limit of image.

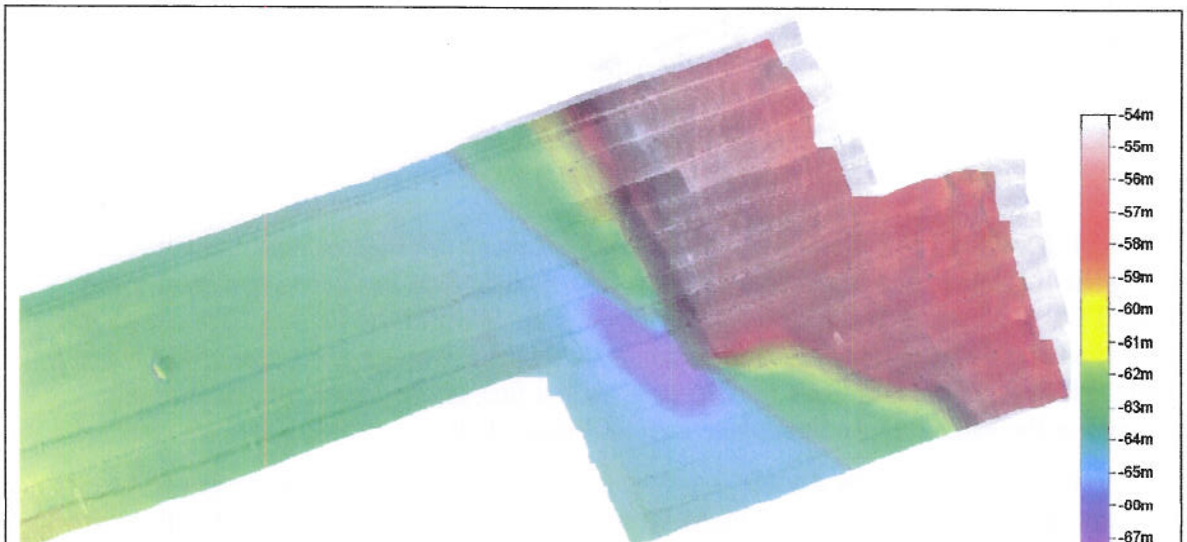


Figure 4.1h – Surface map of Long Bank adjusted to highlight seabed structure on the bank using merged GeoSwath side scan sonar and bathymetric data (10x vertical exaggeration of a 1m grid). Artifacts on this map are largely associated with swath side scan sonar slant range corrections.

A ridge oriented northwesterly separates Long Bank from the lower region between the banks. A pronounced depression is present at the sharp southwestern edge of the bank. Swath side scan sonar data (Figures 4.1.2c, 4.1.2d and 4.1.2h) suggests that the dominant substrate of Long Bank is sandy gravel and cobbles.

4.2 TOWED SIDE SCAN SONAR

Towed side-scan sonar results are presented as mosaics of gray or color shaded information. In general, weak signal returns correspond to smooth seafloor substrates (e.g., fine sediments with little micro-topography), soft materials that absorb the signal, or seabed sloping away from the signal source (towfish). These features appear lighter gray on the sonar record. Strong signal returns correspond to rough seabed substrates (e.g., gravel, cobble), highly reflective materials, or to a seabed sloping towards the signal source. These features appear as dark gray to black on the sonar record. Features that rise above the seabed (e.g., boulders) reflect more of the sonar energy than the surrounding substrate resulting in strong signal returns. These features often prevent insonification of the area opposite the signal source, resulting in a sonar "shadow" (white portion of the record). The length of these shadows can be used to calculate the approximate height of the elevated features.

The towed side-scan sonar data allowed a more detailed characterization of seabed substrates than characterizations based on GeoSwath data due to greater resolution capabilities provided by the processing software and because of a more desirable signal geometry. The ability to lower the towfish close to the seafloor provided two advantages relative to the swath system. First, the grazing angle of the sonar signals was increased, resulting in better textural discrimination and object detection abilities. Additionally, the ability to manipulate towfish height relative to the thermocline allowed minimization of signal refraction.

4.2.1 PIGEON HILLS SIDE SCAN SONAR

Figure 4.2.1a presents a mosaic of the portion of the Pigeon Hills site surveyed using the Edgetech side scan sonar system. The mosaic data has been processed using both TVG corrections and Beam Angle corrections. Both of the Pigeon Hills are clearly identified. The side scan sonar mosaic suggests that the average grain size of the Pigeon Hills "Plateau" decreases from west to east, with a fine-grained textural discontinuity present in the same longitudinal plane as East Pigeon Hill.

Fine scale sonar "waterfall" imagery (i.e., unprojected data) was reviewed using Chesapeake Technology's SonarWizMAP software. Sonar imagery representative of dominant substrates was captured and positions of captured images were geographically digitized. Figure 4.2.1b provides a spatial index to these sonar images for the Pigeon Hills site. The full set of Pigeon Hill waterfall sonar images are provided as Appendix A in "thumbnail" format. Appendix A has also been provided in an HTML navigable format allowing detailed inspection of full-resolution imagery. Several of the images from Pigeon Hill are presented below as Figures 4.2.1c though 4.2.1f.

FIGURE 4.2.1a

100 KHZ SIDE SCAN SONAR MOSAIC – TOWED SYSTEM

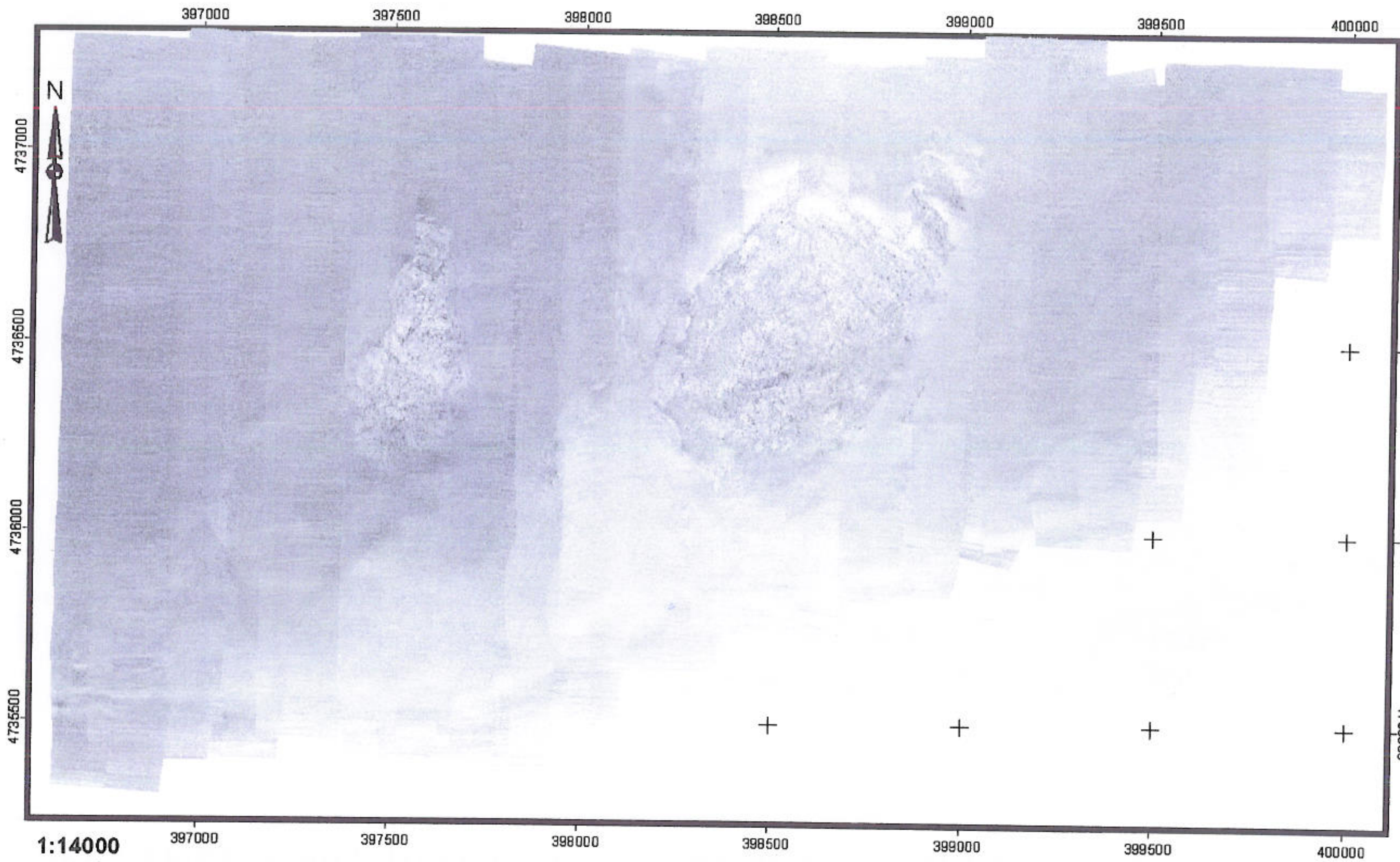
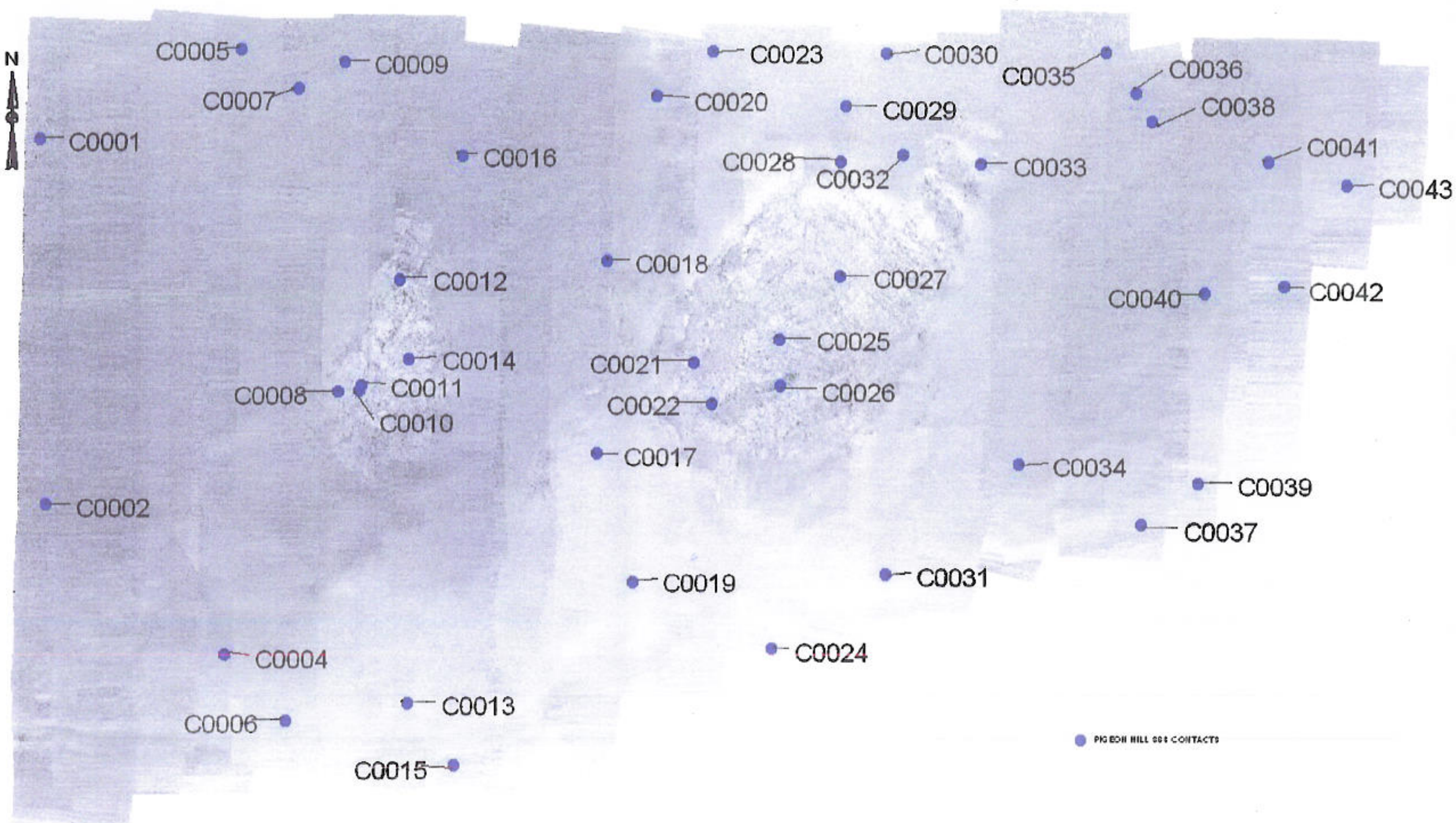


FIGURE 4.2.1b

INDEX TO PIGEON HILL TOWED SIDE SCAN SONAR IMAGERY PRESENTED IN APPENDIX A



1:14000

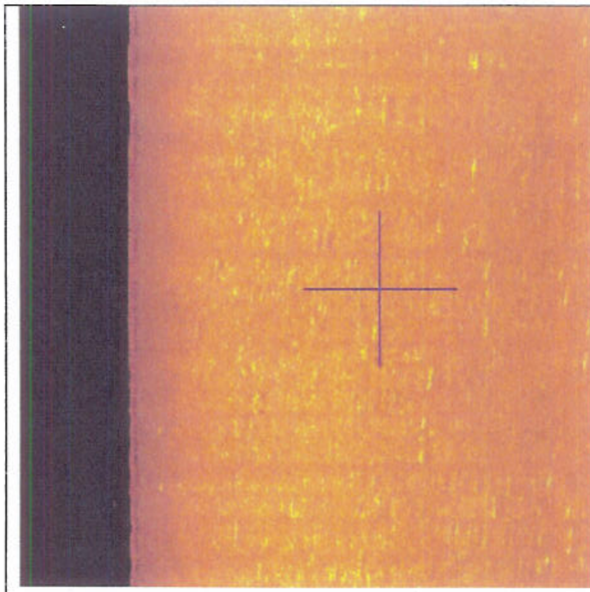


Figure 4.2.1c – Pigeon Hills Contact 16.
Gravel/cobble substrate located north of West Pigeon Hill.

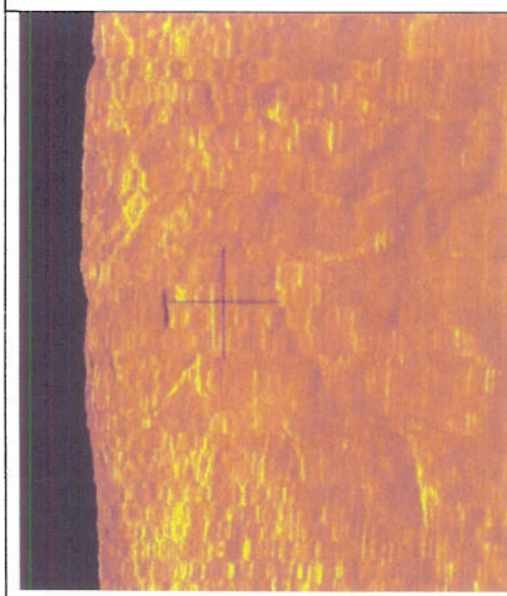


Figure 4.2.1d – Pigeon Hills Contact 14.
Ledge/boulder substrate located at the peak of West Pigeon Hill.

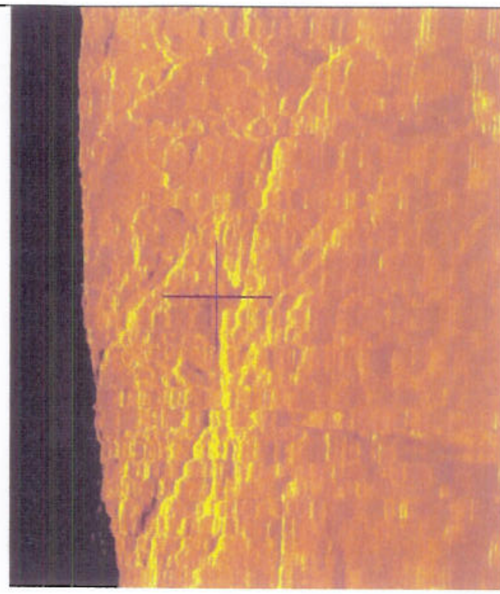


Figure 4.2.1e – Pigeon Hills Contact 27. Striated ledge & crevasse located at the peak of East Pigeon Hill.

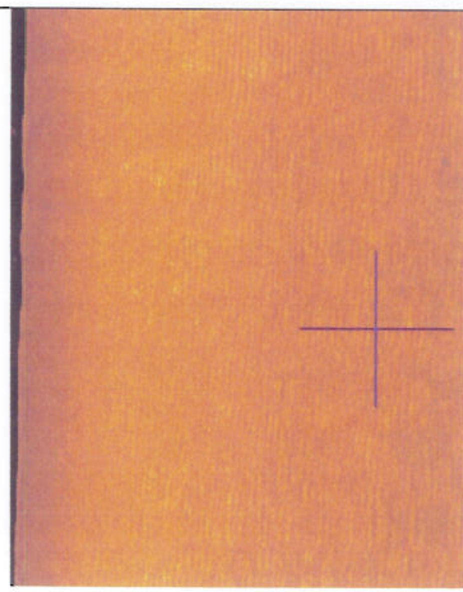


Figure 4.2.1f – Pigeon Hills Contact 30. Sand & gravel ripples north of East Pigeon Hill.

The towed side scan sonar data presented above and in Appendix A shows that the majority of the Pigeon Hills plateau is covered by gravel and cobbles (Figure 4.2.1c). Substrates at East and West Pigeon Hills are dominated by ledge and boulder, with fine striations and narrow crevasses (Figures 4.2.1d and 4.2.1e). Ripples of sand and gravel were observed to the north of East Pigeon Hill (Figure 4.2.1f).

FIGURE 4.2.2a

100 KHZ SIDE SCAN SONAR MOSAIC OF THE STELLWAGEN / LONG BANK STUDY AREA – TOWED SYSTEM

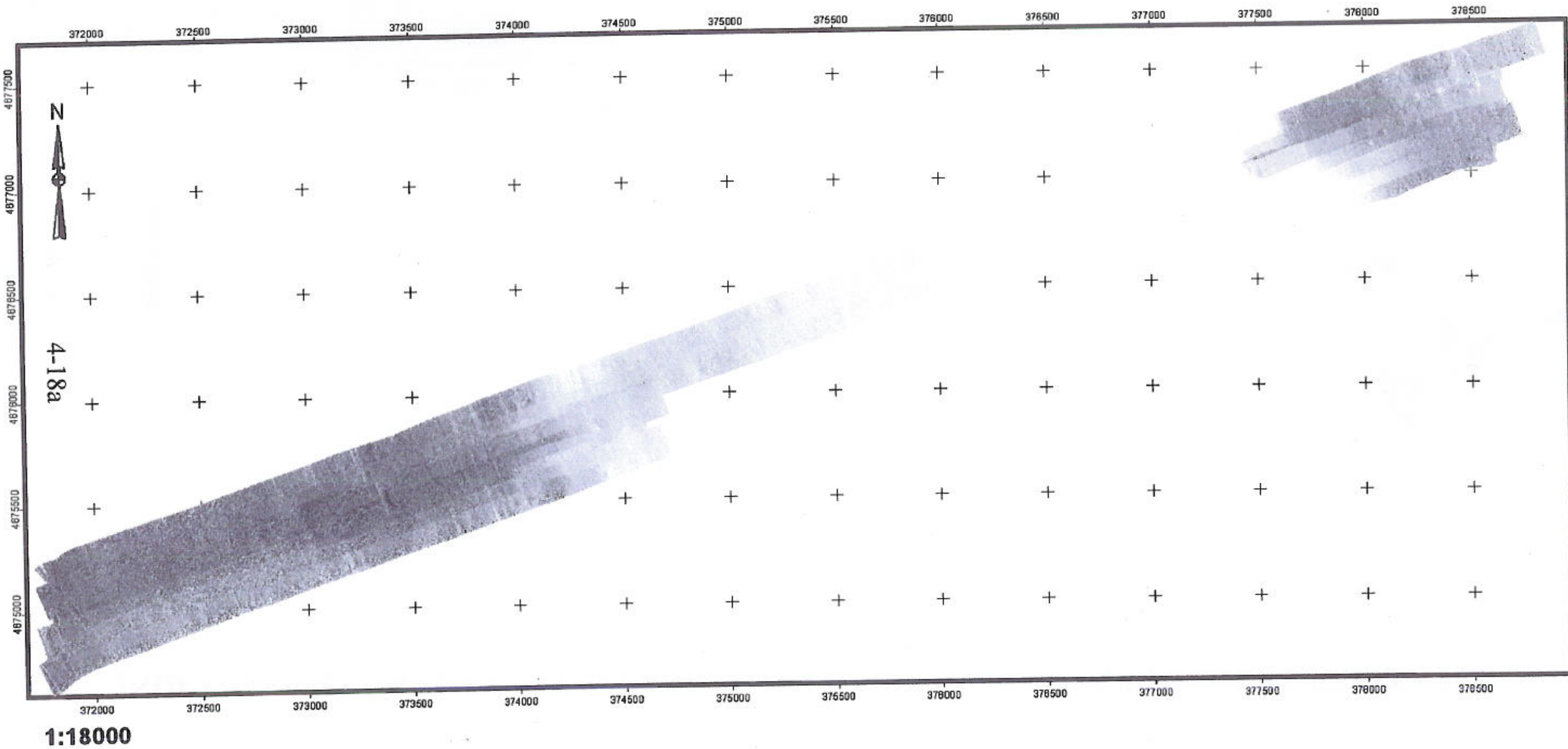
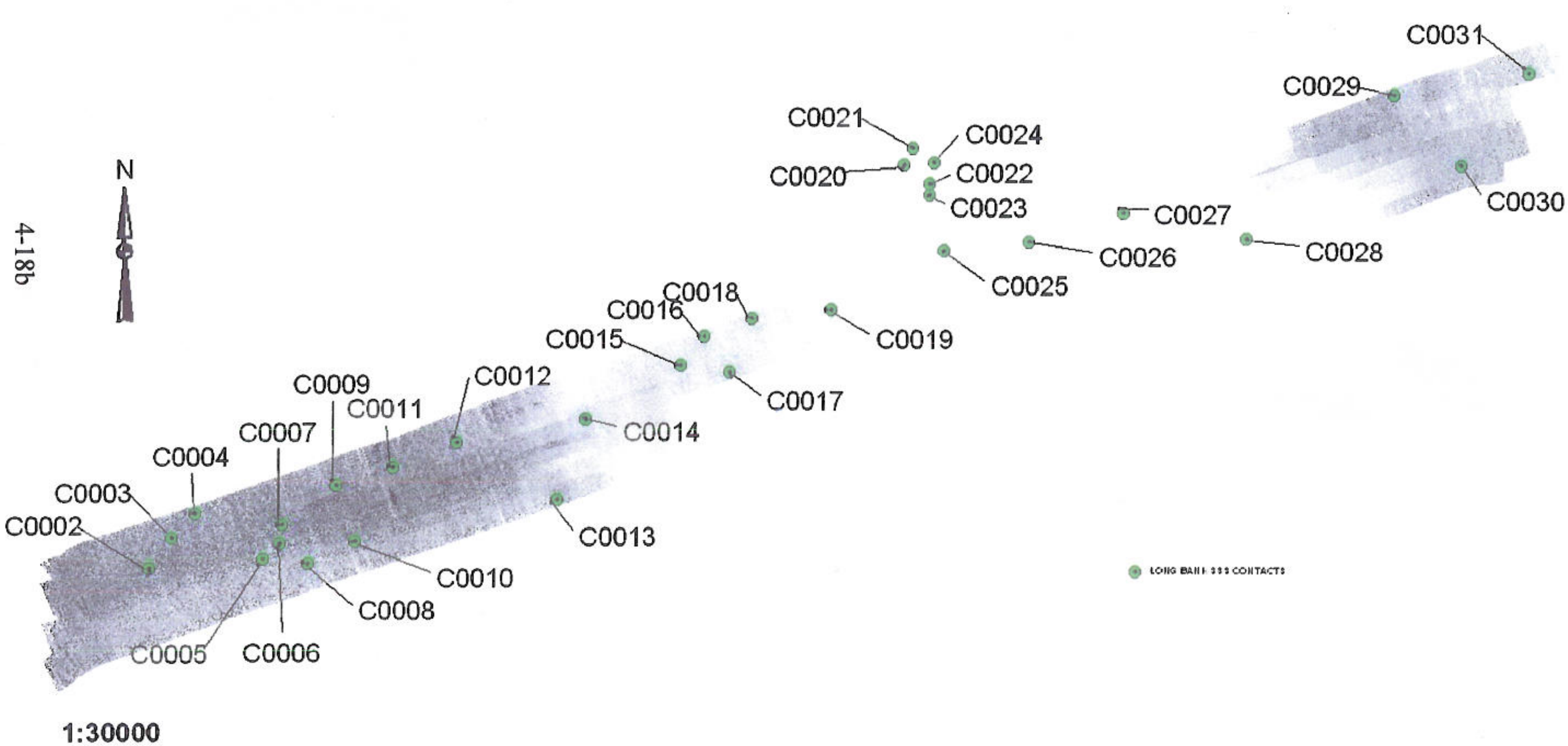


FIGURE 4.2.2b

INDEX TO STELLWAGEN /LONG BANK TOWED SIDE SCAN SONAR IMAGERY PRESENTED IN APPENDIX B



4.2.2 STELLWAGEN / LONG BANK SIDE SCAN SONAR

Figure 4.2.2a presents a mosaic of the portion of the Stellwagen / Long Bank site surveyed using the Edgetech side scan sonar system. The mosaic data has been processed using both TVG corrections and Beam Angle corrections. Both Long Bank and the western bank are clearly identified by their highly reflectivity. The side scan sonar mosaic suggests that the average grain size of the site decreases gradually from the toe of the west bank slope from west to east. Data suggests that substrate within the depression separating the two banks is finest at the eastern side of the trough.

Fine scale sonar "waterfall" imagery (i.e., unprojected data) was reviewed using Chesapeake Technology's SonarWizMAP software. Sonar imagery representative of dominant substrates was captured and positions of captured images were geographically digitized. Figure 4.2.2b provides a spatial index to these sonar images for the Stellwagen / Long Bank site. The full set of site waterfall sonar images are provided as Appendix B in "thumbnail" format. Appendix B has also been provided in an HTML navigable format allowing detailed inspection of full-resolution imagery. Several of the images from the Stellwagen / Long Bank site are presented below as Figures 4.2.2c though 4.2.2h.

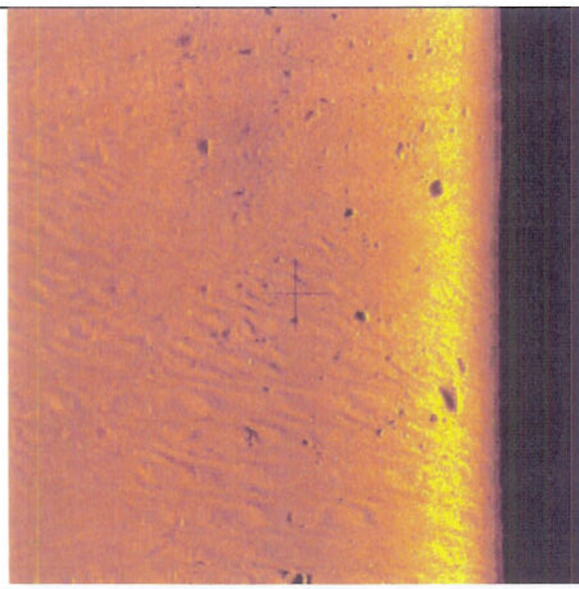


Figure 4.2.2c - Stellwagen / Long Bank Contact 7. Sonar record showing sand waves, gravel, cobbles and boulders on the western bank.

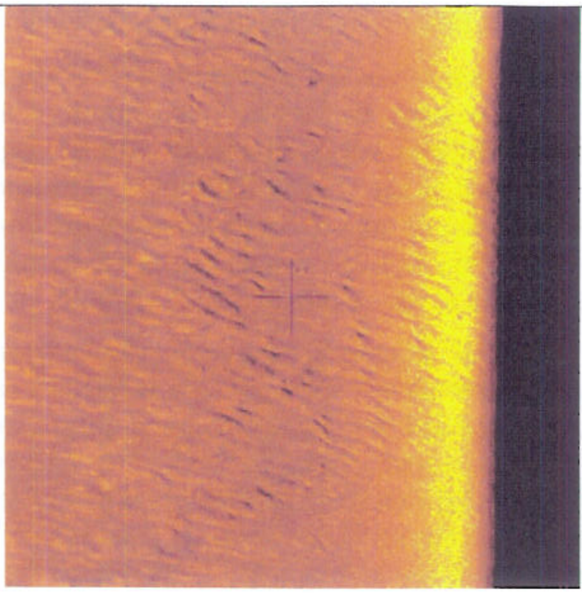


Figure 4.2.2d - Stellwagen / Long Bank Contact 10. Sand and gravel ripples on the western bank.

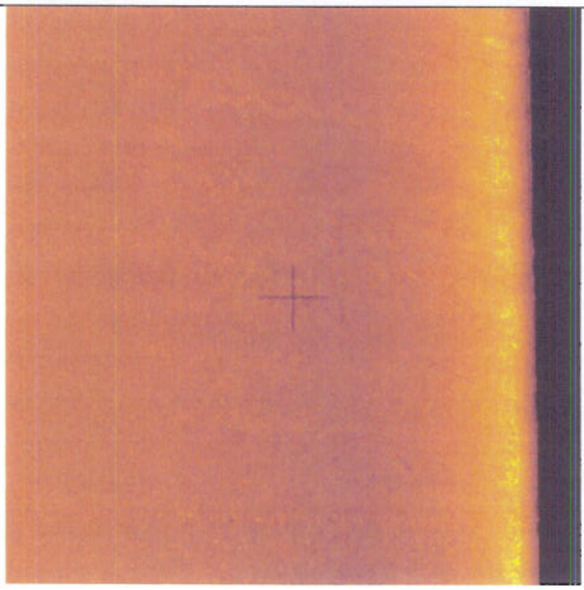


Figure 4.2.2e - Stellwagen / Long Bank Contact 14. Bands of gravel among sand at the toe of the western bank. Record also shows N/S oriented scours from fishing gear.

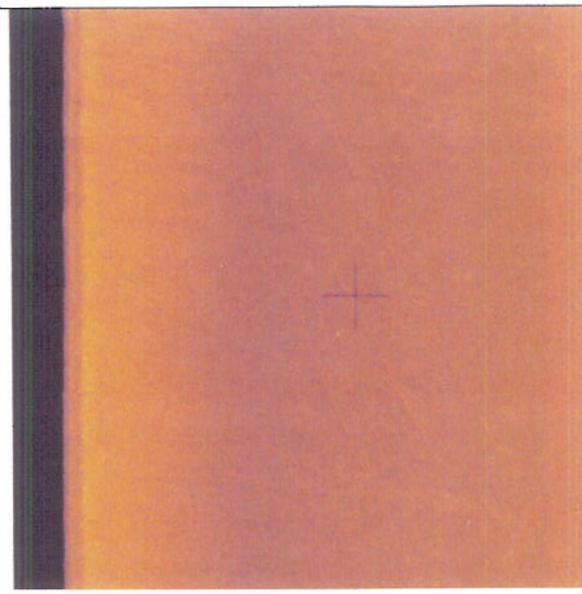


Figure 4.2.2f - Stellwagen / Long Bank Contact 15. Troughs from fishing gear in the coarse sandy bottom at the western edge of the depression between banks.

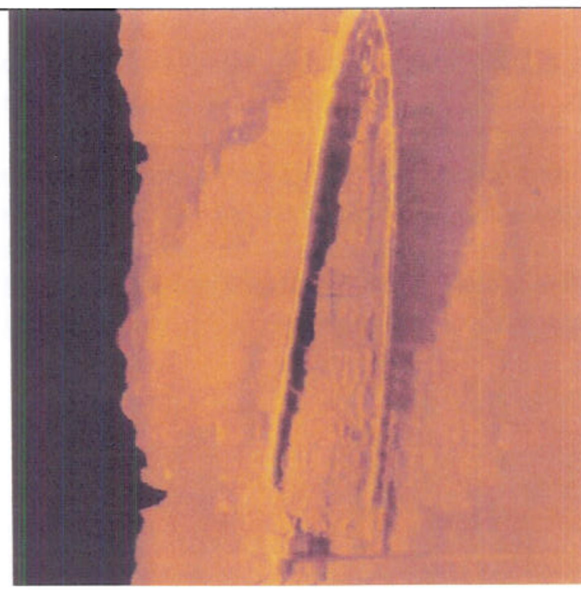


Figure 4.2.2g - Stellwagen / Long Bank Contact 23. The "Bronze wreck" surrounded by fine silty sand. The data suggests scour and coarser sand adjacent to the wreck.

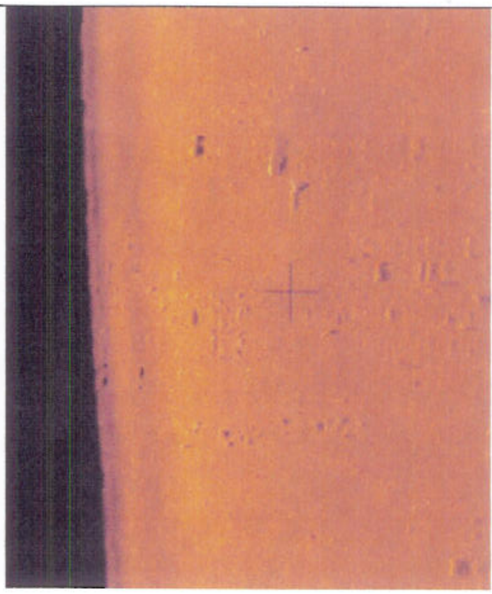


Figure 4.2.2h - Stellwagen / Long Bank Contact 31. Relatively flat area dominated by gravel, cobble and boulders at the toe of Long Bank.

Examination of towed side scan sonar data shows that the site possesses a diverse range of benthic habitats. At the western edge of the survey area, data suggests ledge/boulder substrate. The surface of the western bank appears to be dominated by a complex distribution of mobile sand and gravel interspersed with cobbles and boulders. Substrate particle size appears to gradually decrease with depth and distance east, with clear transitions from sand/gravel to fine sand to silty sand or sandy silt. The data show an abrupt change from fine sediments to coarse-grained substrate at the toe of Long Bank. The surface of Long Bank is shown to be dominated by sandy gravel, cobbles and boulders.

4.3 SUB-BOTTOM PROFILING

Figure 4.3a depicts the trackline of the sub-bottom sonar profile collected at the Pigeon Hills site. Figure 4.3b depicts the 10-kHz sub-bottom data in cross-section. Sonar penetration was minimal along the majority of the trackline, possibly due to the scattering effect of the gravel/cobble seabed. Substantial penetration was achieved at the toe of the slope to the south of East Pigeon Hill. Data in this area suggest a coarse sub-surface strata approximately 5 m below the sediment surface and a deeper impenetrable reflective layer as much as 15 m beneath the sediment surface. These data suggest that the fine substrate documented in this trench is likely a thin veneer underlain by coarse geological features.

Figure 4.3c depicts the trackline of the sub-bottom sonar profile collected at the Stellwagen / Long Bank site. Figure 4.3d depicts the 10-kHz sub-bottom data in cross-section. Penetration on Long Bank was negligible, likely due to the scattering effect of the gravel/cobble seabed. However, in the depression to the west of Long Bank the sub-bottom profiler successfully penetrated sediment to a strong reflector 6- to 19-m below the sediment surface. This reflector is likely bedrock or basal till. The upper approximately 4-5 m of sediment in this depression has an acoustic signature which suggests fine grained sediment. Beneath this surficial layer the profile identifies multiple layers of coarser sediments, likely coarse sand and gravel.

FIGURE 4.3a

TRACK LINE FOR PIGEON HILL SUB-BOTTOM PROFILE
DEPICTED ON FIGURE 4.3b

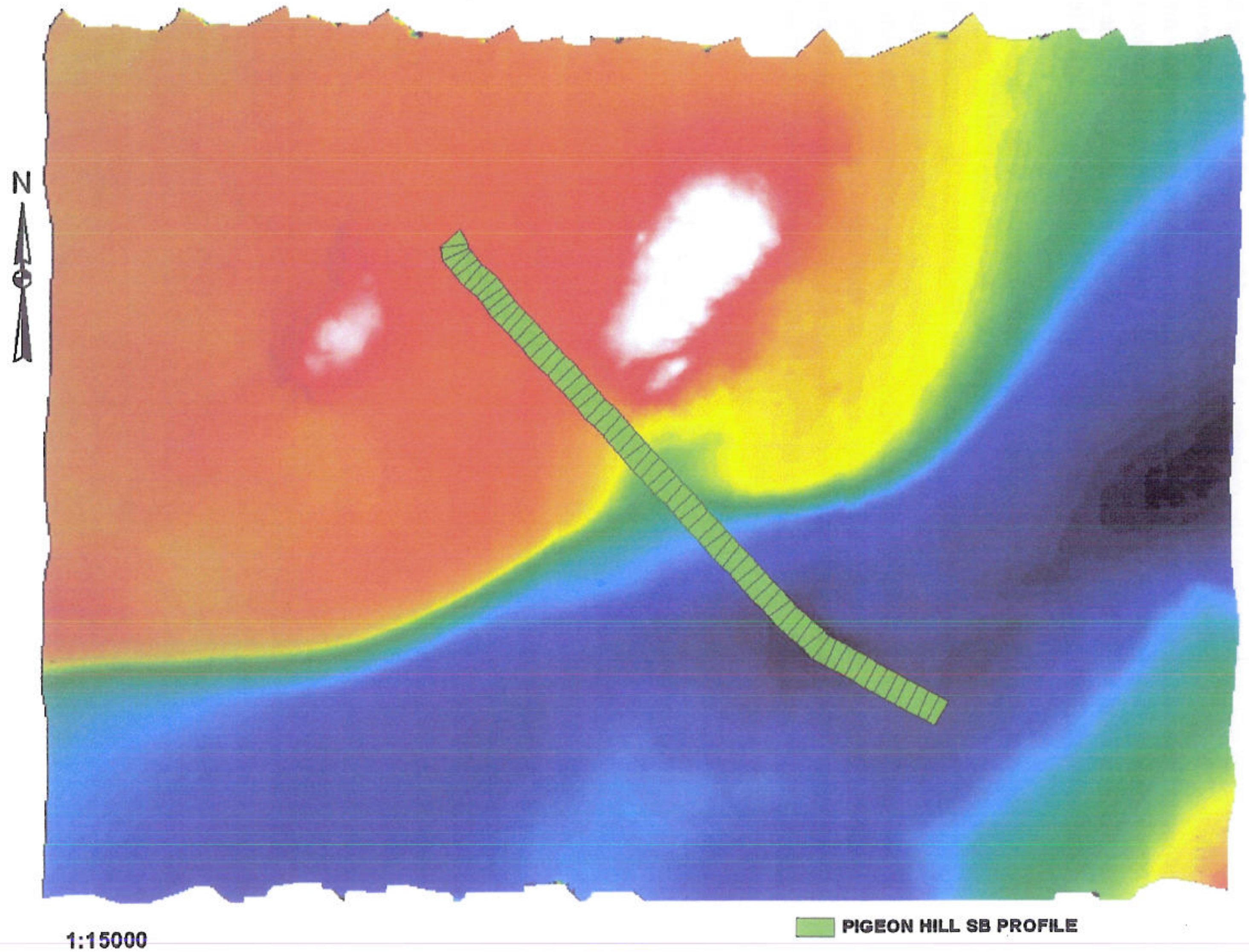


FIGURE 4.3b
REPRESENTATIVE SUB-BOTTOM PROFILE FROM PIGEON HILLS

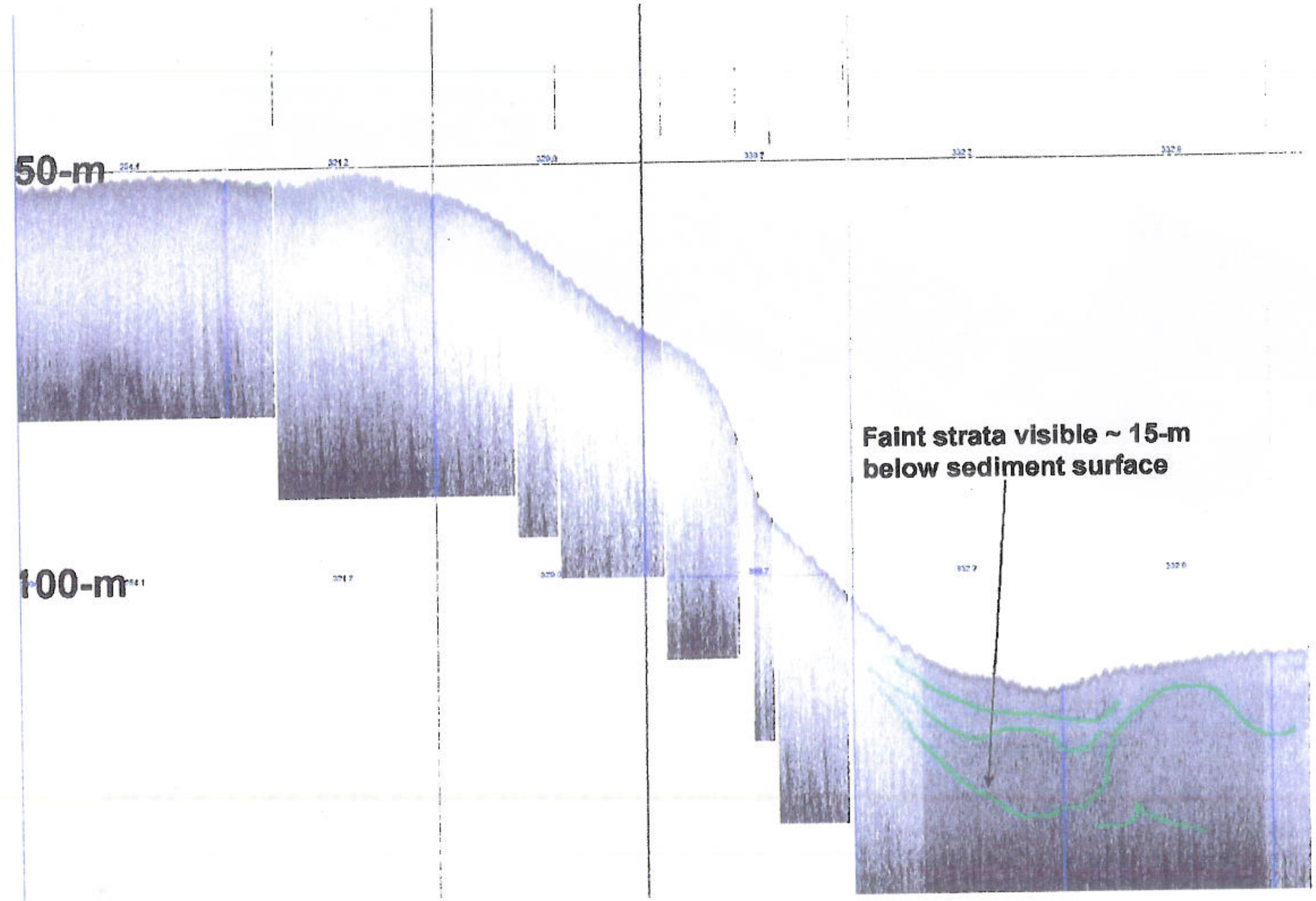


FIGURE 4.3c

TRACK LINE FOR STELLWAGEN / LONG BANK SUB-BOTTOM PROFILE
DEPICTED ON FIGURE 4.3d
(transect start at eastern end)

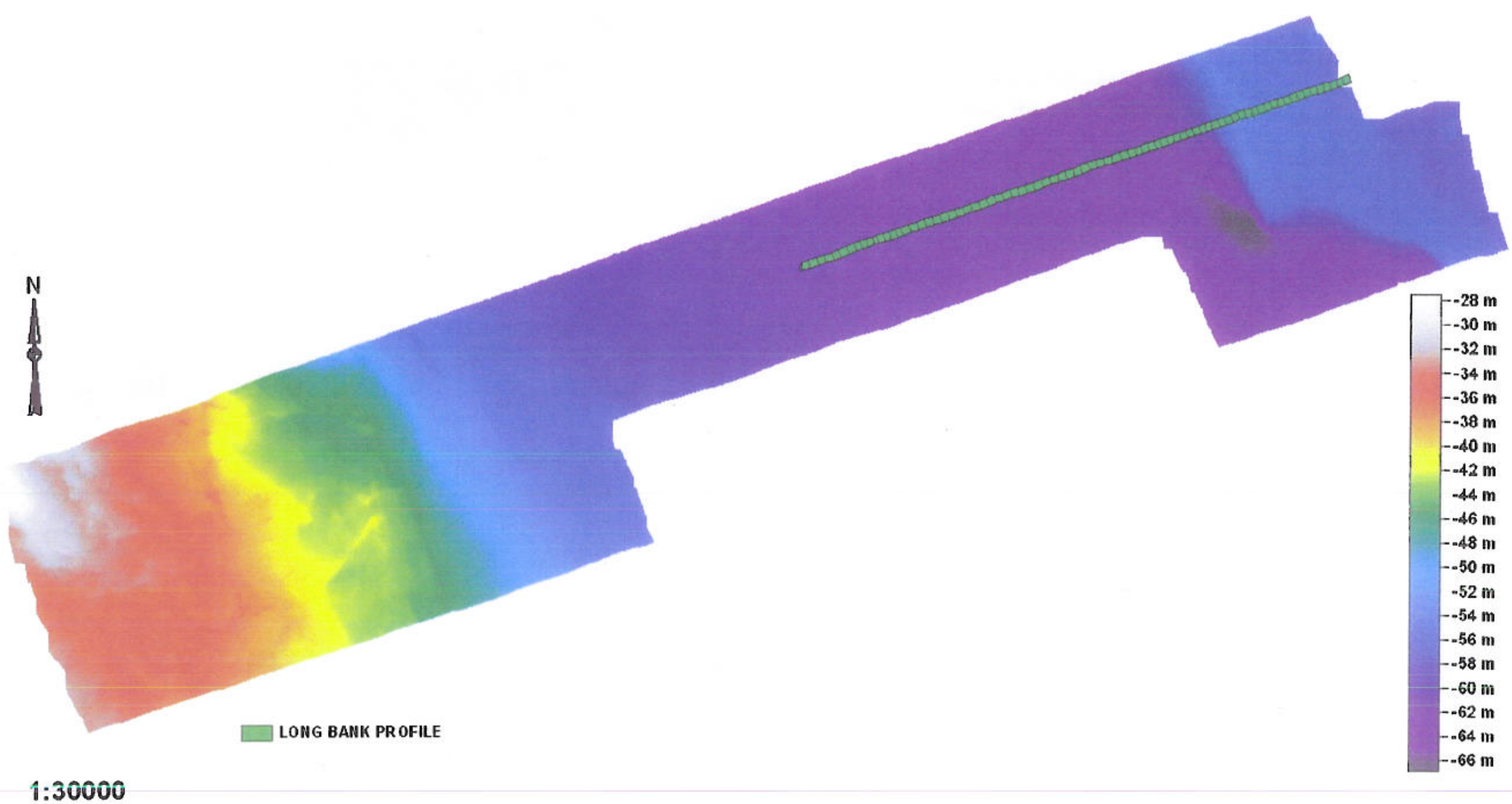
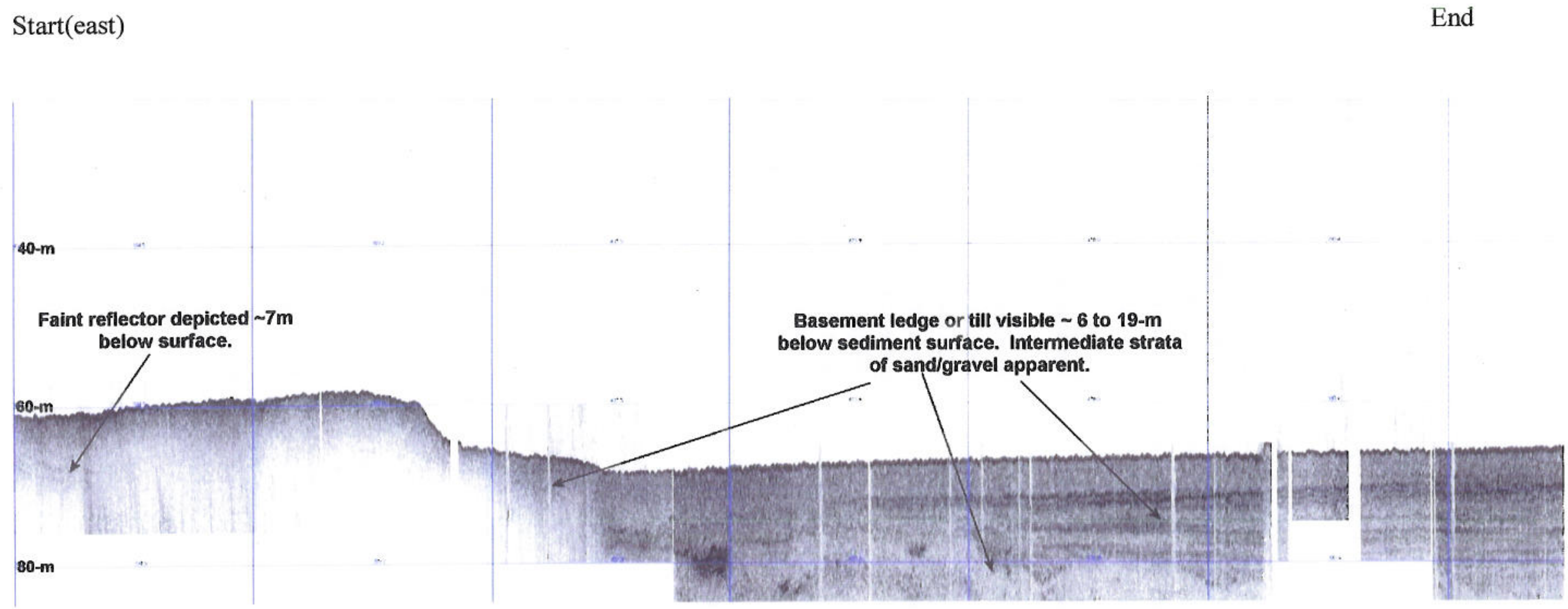


FIGURE 4.3d

REPRESENTATIVE SUB-BOTTOM PROFILE FROM STELLWAGEN / LONG BANK



4.4 VIDEO RESULTS

4.4.1 CR VIDEO SLED RESULTS

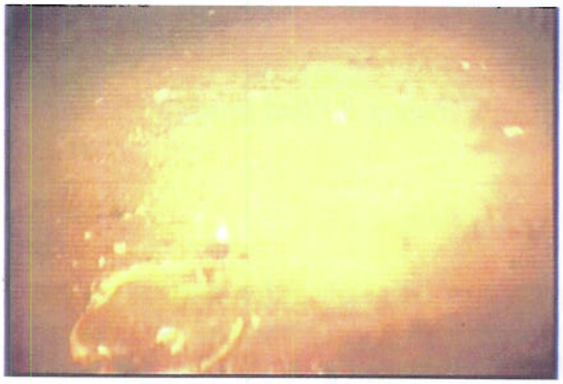
4.4.1.1 BOTTOM HABITAT OBSERVATIONS

Auster et. al (1998) developed a hierarchical approach for classifying marine bottom habitats in the outer continental shelf of the northwest Atlantic. Sediments are classified along a gradient of grain sizes from mud to boulders. The various forms these take and the associations of the infauna and epifauna with sediments produce a wide diversity of habitat types for fish and associated fauna. The eight general habitat categories increase from simple (Category 1) to highly complex (Category 8).

Habitat Category	Description	Rationale	Complexity Score
1	Flat sand and mud	Areas with no vertical structure such as depressions, ripples or epifauna	1
2	Sand waves	Troughs provide shelter from current; previous observations indicate that species such as silver hake hold position on the downcurrent sides of sand waves and ambush drifting demersal zooplankton and shrimp	2
3	Biogenic structures	Burrows, depressions, cerianthid anemones, hydroid patches; features that are created or used by mobile fauna for shelter	3
4	Shell aggregates	Provide complex interstitial spaces for shelter; also provide a complex, high-contrast background that may confuse visual predators	4
5	Pebble-cobble	Provide small interstitial spaces and may be equivalent in shelter value to shell aggregate, but less ephemeral than shell	5
6	Pebble-cobble with sponge cover	Attached fauna such as sponges provide additional spatial complexity for a wider range of size classes of mobile organisms	10
7	Partially buried or dispersed boulders	Partially buried boulders exhibit high vertical relief; dispersed boulders on cobble pavement provide simple crevices; the shelter value of this type of habitat may be less or greater than previous types based on the size class and behavior of associated species	12

8	Piled boulders	Provide deep interstitial spaces of variable sizes	15
Auster et. Al (1998)			

All eight major bottom habitats as described by Auster et al (1998) were encountered within the Pigeon Hills and Stellwagen/Longbank survey area and are illustrated in the screen captures of the underwater video footage below.



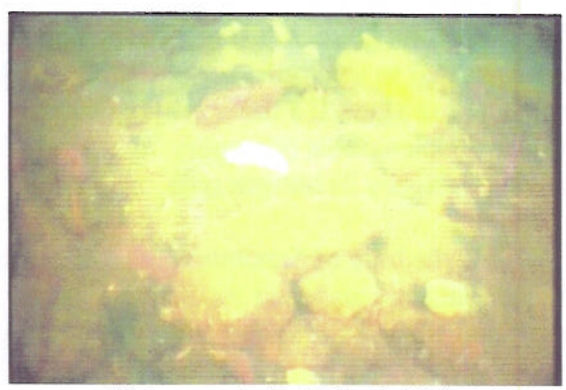
Category 1 - Flat Sand Bottom

Category 2-Sand Waves

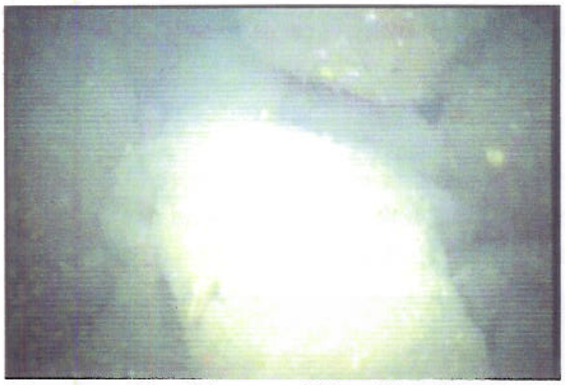
Category 3 - Sandy Mud Bottom

Category 4 - Shell Aggregate Bottom

Category 5 - Pebble-Cobble Bottom



Category 6- Pebble-Cobble w/sponge cover



Category 7 - Dispersed Boulder Bottom Ledge

Category 8 Piled Boulder/Rock

Pigeon Hills Fall 2004 Video Survey Habitat Observations

During the fall 2004 video survey at the Pigeon Hills, eight video drifts as shown in Figure 4.4.1a, were performed in the deeper waters surrounding East and West Pigeon Hills. To the north and east of East Pigeon Hill, the bottom was predominately the flat sand (Category 1) and pebble cobble bottom (Category 5) with a few areas of low amplitude sand waves (Category 2) and shell aggregate (Category 4) bottom type. To the south of East Pigeon Hill, a mud/sand (Category 3) bottom at base of the slope in 70-80 meters of water transitioned to hard sand and cobble bottom. To the south and west of West Pigeon Hill, the bottom was mostly pebble-cobble and boulder (Category 7) habitat. Habitat classifications for each of the video drifts on the fall survey at Pigeon Hills are presented in Table 4.4.1-1

Pigeon Hills Spring 2005 Video Survey Habitat Observations

During the spring 2005 video survey, 8 video drifts were performed on or in close proximity to West and East Pigeon Hills and one additional transect was performed at the base of Sanctuary Hill (Figure 4.4.1b). To the west of West Pigeon Hill, pebble-cobble bottom (Category 5) habitat was found. On top of West Pigeon Hill the bottom was piled boulders and rock ledge bottom (Category 8) with sand channels with some shell. On top of East Pigeon Hill rock ledge with sand channels was also observed (Category 8). However, due to shallower water depths, the ledge was covered with encrusting and branching red algae. To the northwest of East Pigeon Hill the bottom transitioned to a boulder/pebble-cobble (Category 7/Category 5) and a hard sand bottom with subtle sand waves, (Category 2) bottom type.

At the base of Sanctuary Hill, the bottom was mostly pebble-cobble with a few areas of flat sand and sand waves (Category 1 and 2). Habitat classifications for each of the video drifts on the spring survey at Pigeon Hills are presented in Table 4.4.1-2.

FIGURE 4.4.1A
VIDEO DRIFTS – PIGEON HILL
FALL

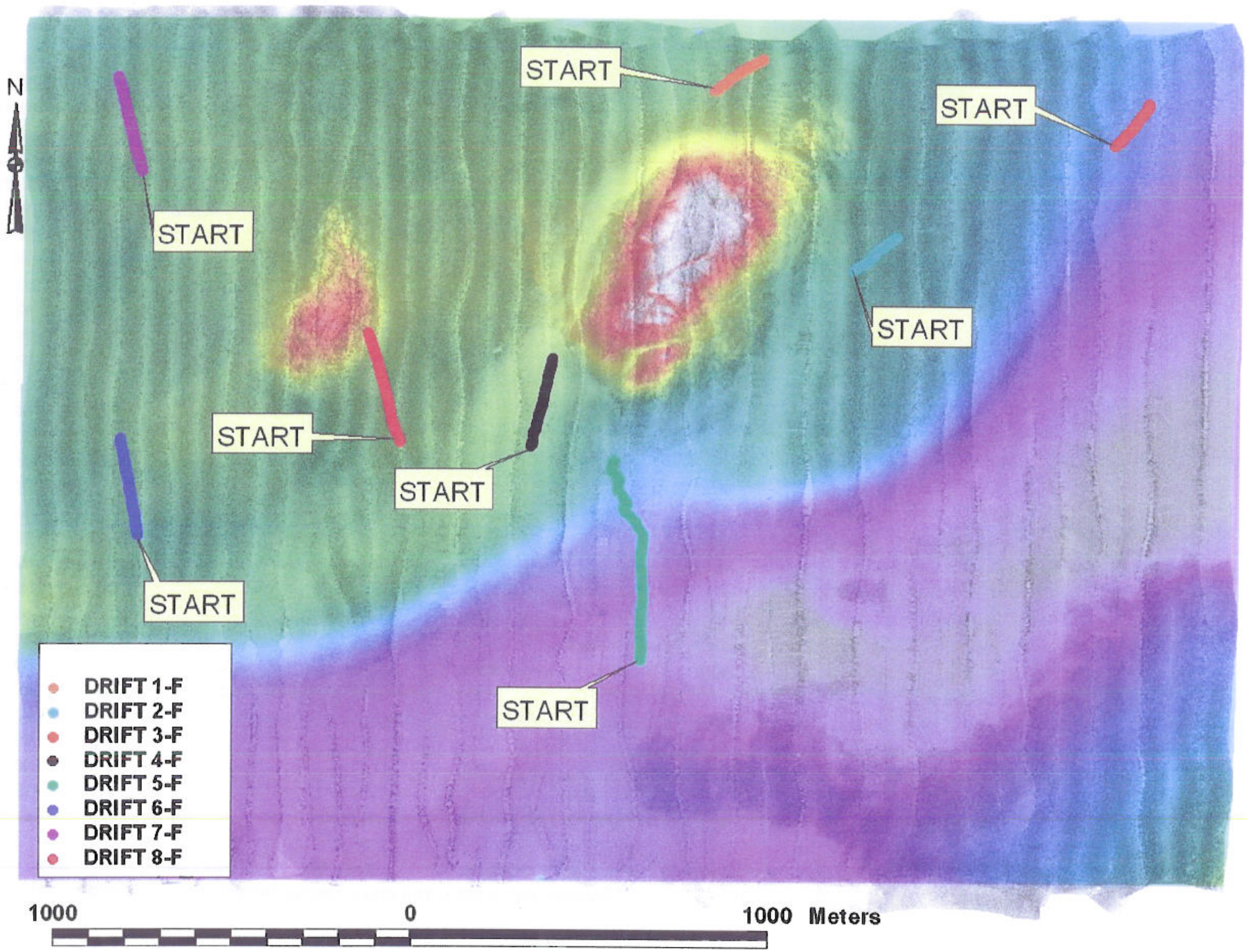


Table 4.4.1-1 Habitat Classifications Pigeon Hills Fall Video Sled Survey

Time / Drift	PH Fall-1	PH Fall-2	PH Fall-3	PH Fall-4	PH Fall-5-1	PH Fall 5-2	PH Fall-6	PH Fall-7	PH Fall-8
0	1-S	1,5-S,PC	1-S	1,5-S,PC	3-SM		1,7-S,BO	5-PC	
30	2-SW			4-SH			2,5-SW,PC	5-PC	5-PC
1:00			1-S						
1:30									
2:00					3-SM				
2:30	1,5S,PC						1,5-S,PC	5-PC	
3:00	1,5-S,PC		1,5-S,PC		3-SM				
3:30	2-SW			4-SH					
4:00		2,5-SW,PC	1,5-S,PC				1,5-S,PC		
4:30									
5:00									
5:30	1,5-S,PC	5-PC			3-SM	1,5-S,PC	1,5-S,PC		
6:00	1,5-S,PC	1-S		4-SH					
6:30									
7:00	2,5-SW,PC	S,GR		1,4-S,SH					
7:30			1,5-S,PC			1-S	5-PC		5-PC
8:00									7-BO
8:30								5-PC	
9:00	5-PC	2,5-SW,GR							
9:30	1-S			1,4-S,SH		1-S			
10:00					3-SM			5-PC	
10:30							5-PC	5-PC	
11:00					4-SH	4-SH		7-BO	
11:30								7-BO	
12:00	2-SW					4-SH			
12:30						1,7-S,BO	5-PC		
13:00						1-S			5-PC
13:30						1-S	5-PC		
14:00	1,5-S,PC	5-PC							
14:30		2,5-SW,PC					5-PC		
15:00		1-S		1,4-S,SH	1-S	4-SH		5-PC	5,7-PC,BO

1-Sand (S)
2-Sand waves (SW)
3-Muddy/sand (MS)
4-Shell aggregates (SH)
5-Pebble/cobble (PC)
6-Pebble/cobble w/sponge (PCS)
7-Dispersed bolders (BO)
8-Rock ledge/piled bolders (RL)

FIGURE 4.4.1B
VIDEO DRIFTS – PIGEON HILL
SPRING

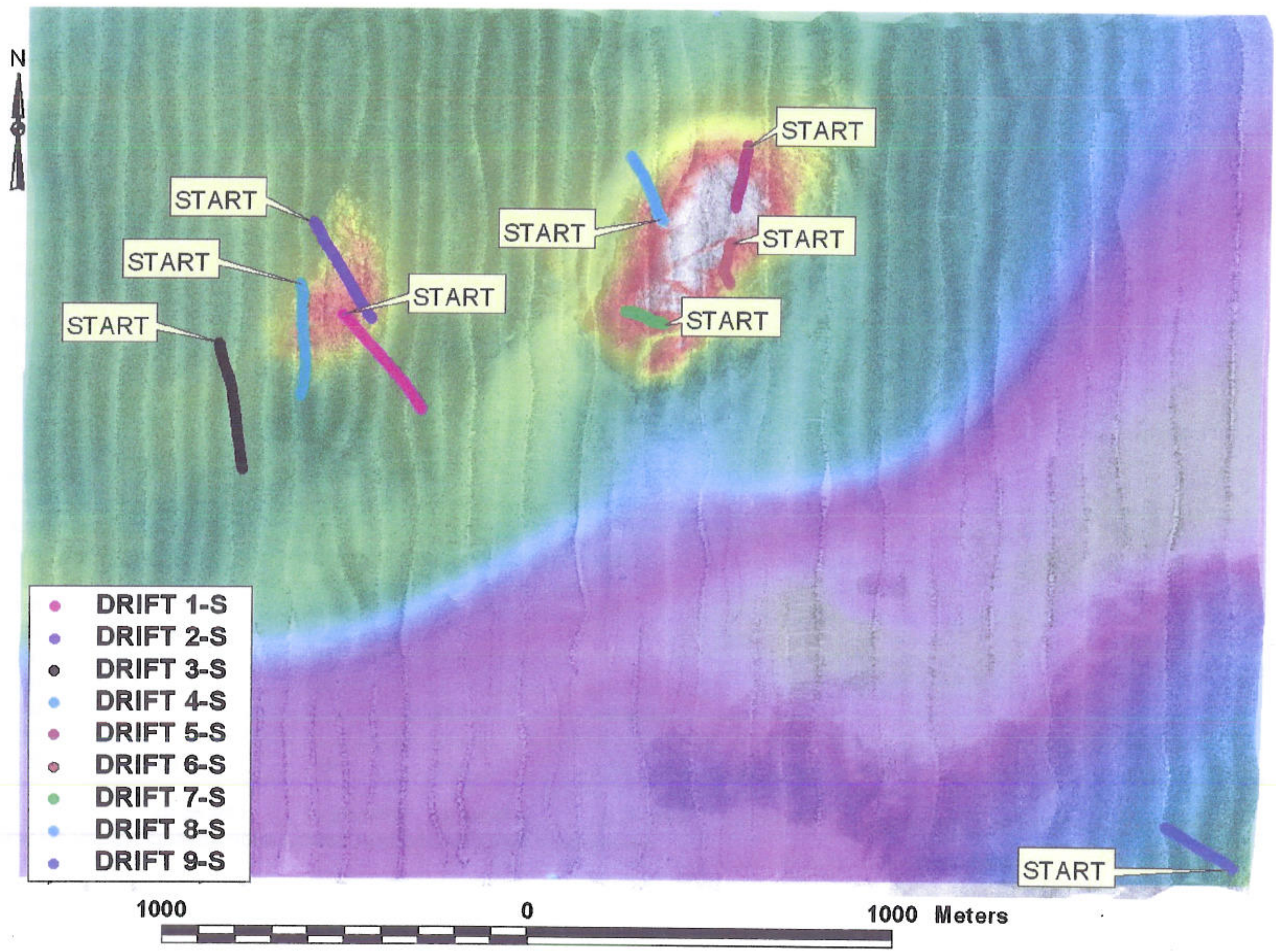


Table 4.4.1-2 Habitat classifictions Pigeon Hills Spring Video Sled Survey

Time / Drift	PH Spring-1	PH Spring-2	PH Spring-3	PH Spring-4	PH Spring-5	PH Spring-6	PH Spring-7	PH Spring-8	SH Spring-9
0	8-RL	7-BO	5-PC	7-BO	1-S	8-RL	8-RL	8,7-RL,BO	5,7,8-PC,BO,RL
30								7-BO	
1:00			5-PC	7,5-BO,PC				1,8-S,RL	
1:30		7-BO				8-RL	1,8-S,RL		
2:00									7-BO
2:30	7-BO	7-BO			1-S			1-S	
3:00		7-BO		7-BO				7-BO	
3:30		7-BO							1,5-S.PC
4:00		8-RL	7,5-BO,PC	8-RL					
4:30					1,8-S,RL		8-RL	1,7,8S,BO,RL	
5:00	8-RL	7-BO	1,5-S,PC					8-RL	
5:30					8-RL		1-S		
6:00								8-RL	
6:30				8-RL	8-RL	8-RL		1,8-S,RL	
7:00	4,8-SH,RL				8-RL				
7:30		7-BO		7-BO			8-RL	5,7PC,BO	
8:00			1,5-S,PC		8-RL				5-PC
8:30									
9:00		8-RL		7-BO					
9:30	8-RL			1-7-S,BO	8-RL			1-S	5,7-PC,BO
10:00						8-RL	8-RL		
10:30		8-RL			8-RL	1,8-S,RL			
11:00		8,7-RL,BO			1,8-S,RL				
11:30			1,5-S,PC	7-BO				2-SW	
12:00		8-RL							
12:30									5-PC
13:00							8-RL		
13:30	8,6-RL,PC		1,5-S,S,PC	7-BO	8-RL				5-PC
14:00				7-BO			8-RL		
14:30		7-BO		7-BO				2-SW	
15:00			5-PC		RL				

1-Sand (S)
2-Sand waves (SW)
3-Muddy/sand (MS)
4-Shell aggregates (SH)
5-Pebble/cobble (PC)
6-Pebble/cobble w/sponge (PCS)
7-Dispersed bolders (BO)
8-Rock ledge/piled bolders (RL)

Stellwagen/Longbank Fall 2004 Video Survey Habitat Observations

In the fall 2004 video survey at Stellwagen/Long Bank study site, a total of nine video sled drifts were performed (Figure 4.4.1c). At the eastern end of the study site on Long Bank, the bottom is primarily pebble-cobble (Category 5) with occasional small boulders. To the west, on the slope of the bank, the bottom transitions from a hard sand (Category 1) to a sandy mud (Category 3). This sandy mud bottom habitat is prevalent throughout center of the study site. The video sled transects at the western portion of the study site reveal a primary pebble/cobble habitat (Category 5) with some pebble cobble bottom with sponge cover (Category 6) and limited dispersed boulder habitat (Category 7). Habitat classifications for each of the video drifts on the fall survey at Stellwagen/Long Bank are presented in Table 4.4.1-3.

Stellwagen/Longbank Spring 2005 Video Survey Habitat Observations

The spring video survey at Stellwagen/Long Bank study site included a total of eight video sled drifts (Figure 4.4.1d). Drifts 1 through 3 confirmed the presence of the pebble/cobble (Category 5) on Long Bank and the sandy mud bottom habitat (Category 3) in the 60-meter water depths at the center of the site. The spring survey primarily targeted the hard bottom areas on the western Stellwagen Bank side of the study area. This area was composed primarily of the pebble/cobble (Category 5), pebble/cobble with sponge cover (Category 6), and the dispersed boulder habitats. Habitat classifications for each of the video drifts on the spring survey at Stellwagen/Long Bank are presented in Table 4.4.1-4.

FIGURE 4.4.1C
VIDEO DRIFTS – STELLWAGEN / LONG BANK
FALL

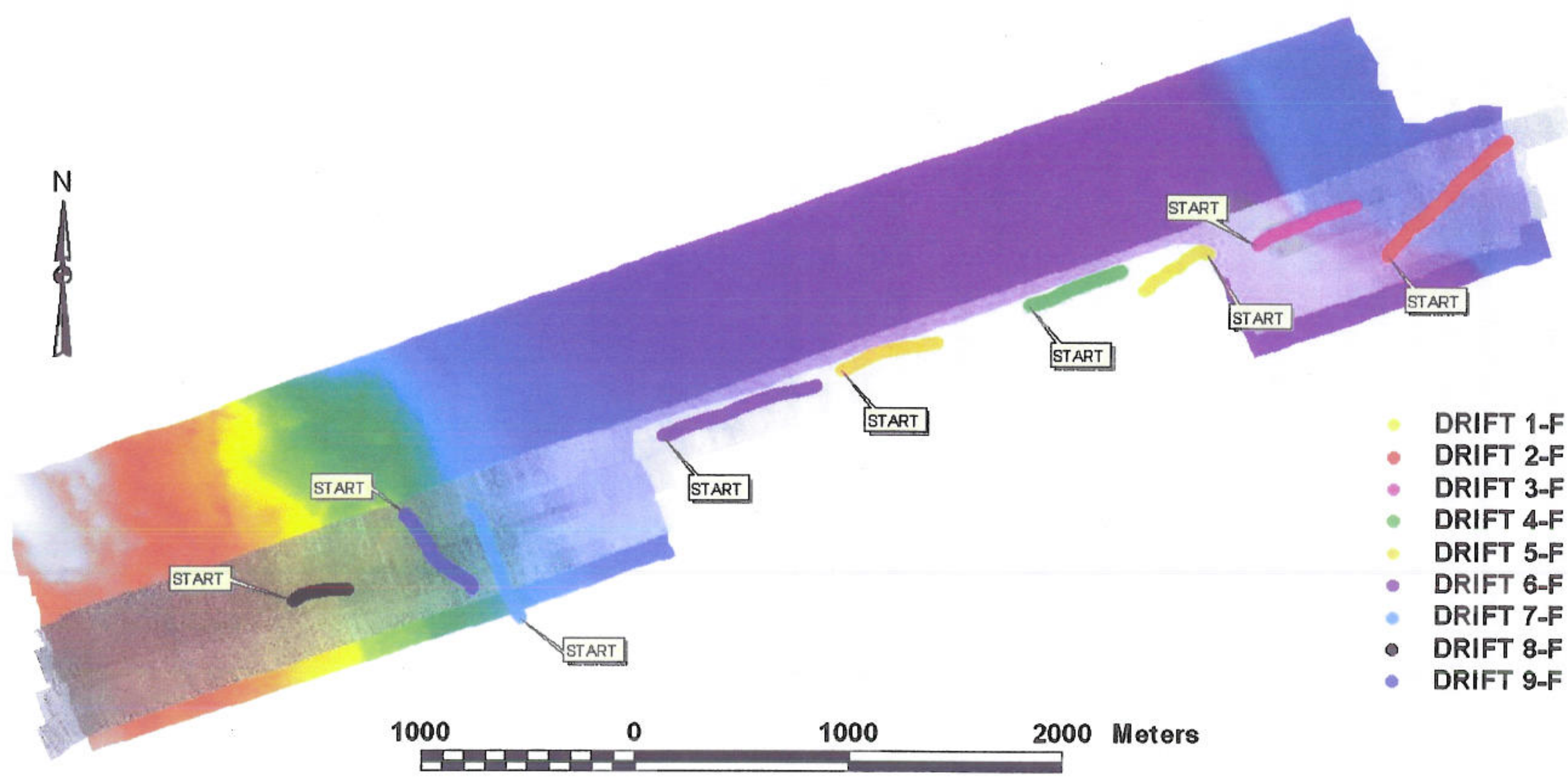


Table 4.4.1-3 Habitat classifications Stellwagen/Long Bank Fall Video Sled Survey

Drift Time	SW Fall-1	SW Fall-2-1	SW Fall-2-2	SW Fall-3	SW Fall-4	SW Fall-5	SW Fall-6	SW Fall-7	SW Fall-8	SW Fall-9
0	3-SM	3-SM		3-SM	3-SM	3-SM	3-SM	5,6-PC,PCS	5,6-PC,PCS	5,6-PC,PCS
30							1-S	2-SW	5,6,7-PC,PCS,BO	5,6-PC,PCS
1:00				3-SM		3-SM				
1:30									5,6-PC,PCS	
2:00									2-SW	
2:30				3-SM	3-SM					
3:00									5,6-PC,PCS	5,6-PC,PCS
3:30			1-S					1-S	7-BO	
4:00		3-SM								
4:30	3-SM							7-BO		
5:00							1-S	2,5,6-SW,PC.PCS		5,6-PC,PCS
5:30		3-SM				3-SM				
6:00										
6:30	3-SM		3-SM		3-SM				2-SW	
7:00				1-S					5,6-PC,PCS	
7:30			5-PC	5-PC						
8:00				5-PC	3-SM	3-SM				1,5,5-S,PC,PCS
8:30								1,5,6-S,PC,PCS		
9:00			5-PC	5-PC						
9:30										
10:00			5-PC					5,6-PC,PCS		
10:30										
11:00										
11:30										
12:00			7-BO							
12:30			5,7-PC,BO							2-SW
13:00				5-PC			1-S			
13:30								1,5,6-S,PC,PCS		
14:00					3-SM					5,6-PC,PCS
14:30										
15:00	MU	MU/S						1,5,6-S,PC,PCS		

1-Sand (S)
2-Sand waves (SW)
3-Muddy/sand (MS)
4-Shell aggregates (SH)
5-Pebble/cobble (PC)
6-Pebble/cobble w/sponge (PCS)
7-Dispersed bolders (BO)
8-Rock ledge/piled bolders (RL)

FIGURE 4.4.1D
VIDEO DRIFTS – STELLWAGEN / LONG BANK
SPRING

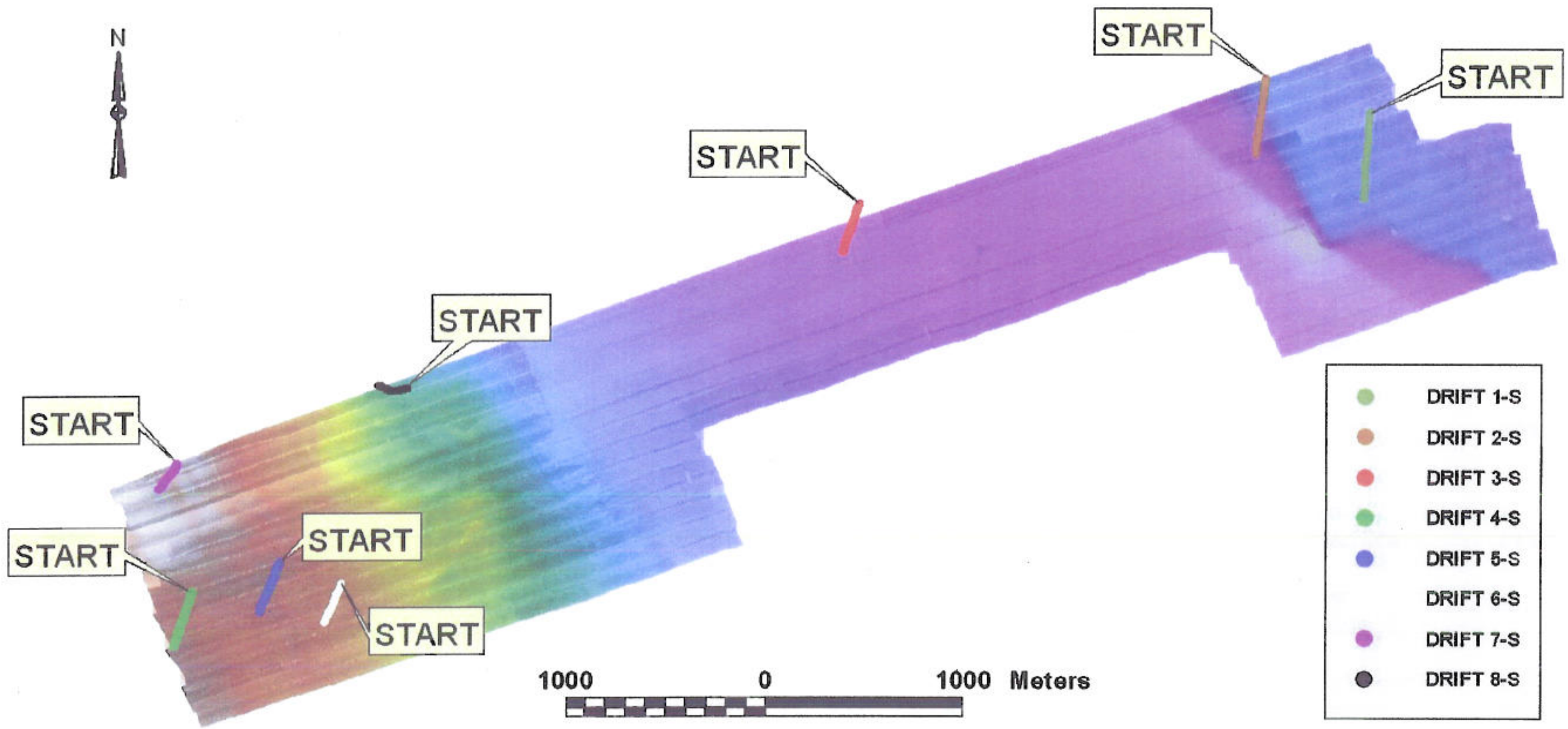


Table 4.4.1-4 Habitat Classifications Stellwagen/Long Bank Spring Video Sled Survey

Time	Drift	SW Spring-1	SW Spring-2-1	SW Spring-3	SW Spring-4	SW Spring-5	SW Spring-6	SW Spring-7	SW Spring-8
0		3-SM	1,5,6-S,PC,PCS	3-SM	5,6,7-PC,PCS,BO	5,6,7-PC,PCS,BO	5,6-PC,PCS	5,6-PC,PCS	5,6-PC,PCS
30						7-BO			
1:00								5,6,7-PC,PCS,BO	
1:30		3-SM							
2:00					7-BO				
2:30						7-BO			
3:00		3-SM		3-SM	5,6-PC,PCS		5,6-PC,PCS	5,6,7-PC,PCS,BO	5,6-PC,PCS
3:30									
4:00			1,5,6-S,PC,PCS				5,6-PC,PCS		
4:30						5,6-PC,PCS			
5:00									
5:30									
6:00			1,5,6-S,PC,PCS	3-SM	5,6-PC,PCS	5,6-PC,PCS	5,6-PC,PCS		5,6-PC,PCS
6:30						7-BO			
7:00								5,6,7-PC,PCS,BO	7-BO
7:30									
8:00									
8:30									
9:00		3-SM	1,5,6-S,PC,PCS	3-SM	5,6-PC,PCS	5,6,7-PC,PCS,BO	5,6-PC,PCS		
9:30								5,6-PC,PCS	
10:00									1,5-S,PC,PCS
10:30									
11:00									
11:30									
12:00		3-SM	1,5,6-S,PC,PCS	3-SM	5,6-PC,PCS	5,6-PC,PCS	5,6-PC,PCS		1,5,6-S,PC,PCS
12:30									
13:00						7-BO			
13:30					2,5,6-SW,PC,PCS				
14:00								7-BO	
14:30									
15:00					1,5,6-S,PC,PCS		7-BO		

1-Sand (S)
2-Sand waves (SW)
3-Muddy/sanc 1-Sand (S)
4-Shell aggregates (SH)
5-Pebble/cobble (PC)
6-Pebble/cobble w/sponge (PCS)
7-Dispersed bolders (BO)
8-Rock ledge/piled bolders (RL)

4.4.1.2 CR VIDEO SLED OBSERVATIONS OF BIOTA

A total of 23 invertebrates, 7 fish species and 2 types of red algae were observed during the fall and spring video surveys at the Pigeon Hills and Stellwagen/Long Bank study sites. A list of the fish and invertebrate species observed during the underwater video surveys at the Pigeon Hills and Stellwagen/Long Bank study sites is provided below.

<u>ALGAE</u>
Red branching algae
Red encrusting algae

<u>FISH</u>
American Pollock (*Pollachius virens*)
Longhorn Sculpin (*Myoxocephalus octodecimspinosus*)
Ocean Pout (*Macrozoarces americanus*)
Red Hake (*Urophycis chuss*)
Rose Fish (*Sebastes fasciatus*)
Skate (*Raja ocellatus*)
Winter Flounder (*Pseudopleuronectes americanus*))

<u>INVERTEBRATES</u>
Bread Crumb Sponge (*Halichondria panicea*)
Encrusting Bryozoan (Ectoprocta)
Finger Sponge (*Haliclona oculata*)
Hermit Crab (*Pagurus* spp.)
Horse Stars (*Hippasteria phrygiana*)
Lamp Shells/Braciopods (*Terbratulina septentrionalis*)
Lobster (*Homarus americanus*)
Northern Red Anemones (*Urticina felina*)
Northern Sea Star (*Asterias vulgaris*)
Purple Sunstars (*Solaster endeca*)
Rock Crabs (*Cancer* spp.)
Sand Anemones (*Cerianthus borealis*)
Sand Dollar (*Echinarachnius parma)*
Sand Shrimp (*Crangon* sp.)
Sea cucumber (*Psolus fabricio*)
Sea Scallop (*Placopecten magellanicus*)
Slender Sea Stars (*Leptasterias* sp.)
Slime Worms (*Myxicola infundibulum*)
Solitary Hydroids (*Corymorpha pendula*)
Spiny Sunstars   (*Crossaster papposus*)
Squid (*Loligo pealei*)
Stalked Tunicates (*Boltenia ovifera*)
Wentletrap (*Epitonium* spp.)

Video screen captures of selected algae, fish and invertebrates from Pigeon Hills and the Stellwagen/Long Bank Study sites for the majority of the video drifts are provided in Appendix 3. A representative subset of these photographs are provided in Plates 4.4.1-1 and 4.4.1-2.

Raw counts of the number of invertebrate and fish species observed on each of the video drift and the presence of algae for the fall and spring surveys at Pigeon Hills and Stellwagen/Long Bank are presented in Tables 4.4.1-5, 4.4.1-6, 4.4.1-7, and 4.4.1-8. The tables also provided the elapsed time and distance of each video drift. The counts have not been normalized for time or distance.

4.4.1.3 SUMMARY OF CR ENVIRONMENTAL VIDEO RESULTS

The dominant invertebrate species observed during the *Pigeon Hills fall survey* included burrowing anemones and slender sea stars that are often the dominant organisms in the muddy sand, flat sand and pebble-cobble bottom type habitat that surrounds East and West Pigeon Hills. The dominant fish species was red hake. This species is usually observed in burrows or seeking shelter around shell or small cobbles. The burrowing anemones were extremely abundant on the slopes in deeper water and the anemone tubes provide potential habitat for juvenile fish species. Sand wave habitat was observed to the east and west of the Pigeon Hills. The shell and cobble found in the troughs of the sand waves also provides good habitat for juvenile fish.

During the *spring survey* at *Pigeon Hills*, the dominant invertebrate species on the rock ledge habitat were stalked sea-squirts and horse stars. The dominant fish were rose fish that were observed seeking shelter in the rocky crevices and large schools of juvenile pollock.

In the *fall and spring surveys* at the *Stellwagen/Long Bank* site, the dominant invertebrate species were slender sea stars and burrowing anemones. Bread crumb sponge was also common at the pebble-cobble bottom habitat. Red hake and winter flounder were the dominant fish species observed during the *fall survey* on the sandy mud, flat sand and pebble cobble bottom habitat.

During the *spring survey* at the *Stellwagen/Long Bank* site, red hake was also the dominant fish in the sandy/mud areas but in general the fish counts on the spring survey were extremely low, especially at the boulder and pebble-cobble habitat.

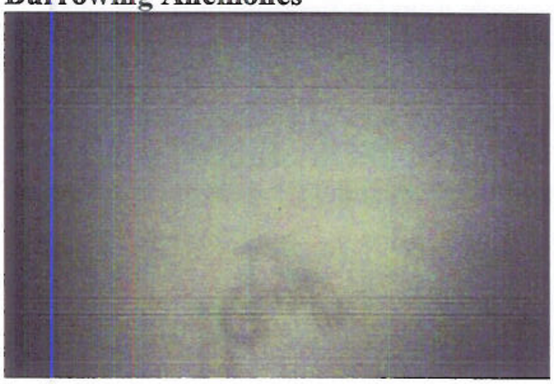
On annual *summer* underwater video surveys for the MWRA at the hard bottom areas off Scituate, MA, codfish were commonly observed at the boulder bottom habitat. Codfish were surprising absent around the boulder habitat at the Stellwagen/Long Bank study area during the EFH study. In addition, CR and ADM participated in a NOAA funded trawl impact study at two fishing sites off Scituate, MA, (Mud Hole and Little Tow) in close proximity to the Stellwagen/Long Bank site. During these *fall* 2001 and 2002 video sled surveys, the fish and invertebrate counts were an order of magnitude

Stalked Tunicates

Northern Sea Star

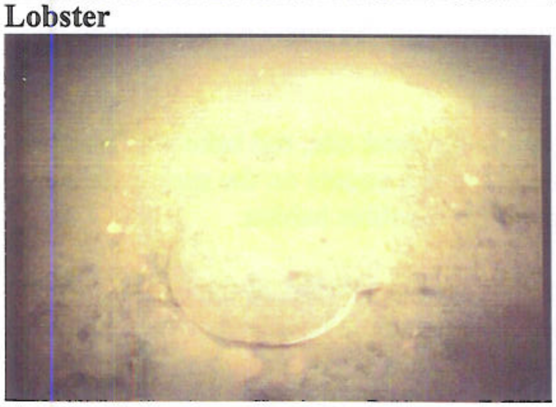
Burrowing Anemones

Slender Sea Star and Horsestar

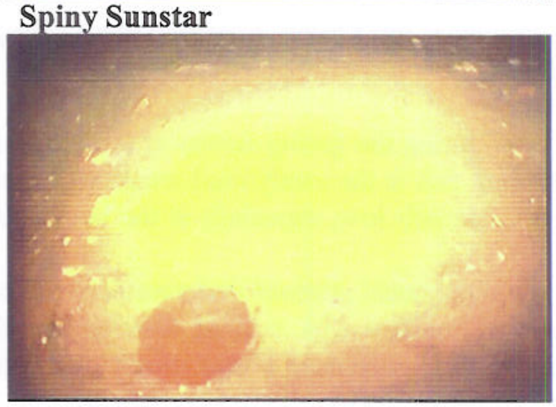


Lobster

Spiny Sunstar

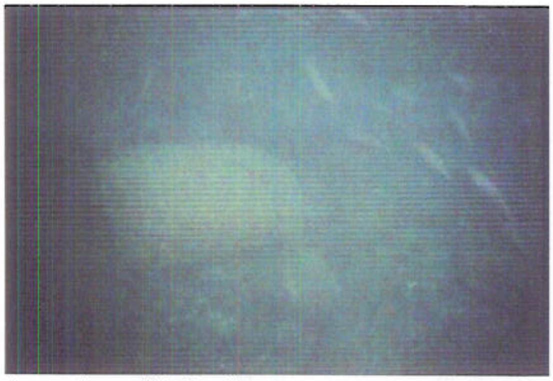


Sea Scallop

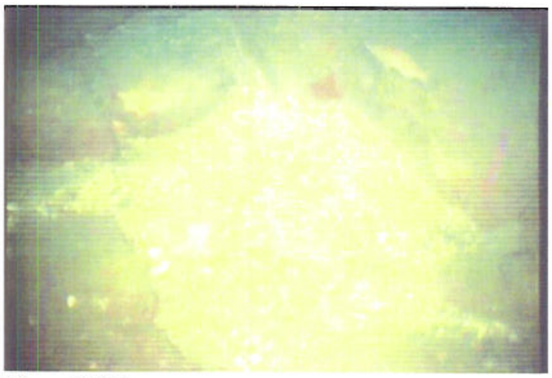


Sand Dollar

Plate 4.4.1-1 Selected Invertebrates from Pigeon Hills and Stellwagen/Long Bank Study Sites


American Pollock


Winter Flounder


Rose Fish


Red Hake


Longhorn Sculpin


Skate

Plate 4.4.1-2 Selected fish from Pigeon Hills and Stellwagen/Long Bank Study Sites

Table 4.4.1-5 Pigeon Hill Fall 2004 Fish & Invertebrate Video Observation Counts

Location	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill
Season	Fall	Fall	Fall	Fall	Fall	Fall	Fall	Fall
Video Drift #	1	2	3	4	5	6	7	8
Transect elapsed time (min)	1502	1505	1528	1911	3000	1455	1503	3040
Transect distance (meters)	165	155	154	255	605	278	277	320
Fish								
Macrozoarces americanus (ocean pout)					1			1
Pseudopleuronectes americanus (winter flounder)								
Urophycis chuss (red hake)					13		1	2
Juvenile Myoxocephalus spp. (sculpin)					1			
Myoxocephalus spp. (sculpin)			1					4
Invertebrates								
Leptasterias tenera (sea star)	27	47	16	4	28	0	12	99
Cancer spp. (rock crab)								
Placopecten magellanicus (sea scallop)	2	2	8	5	3	8	0	0
Myxicola infundibulum (slime worm)	0	2	0	0	5	0	0	0
Solaster endeca (purple sunstar)	1							
Pagurus spp.Hermit crab	0	1	0	0	0	0	0	0
*Cerianthus borealis (*burrowing anemones*)*	18	10	488	14	585	20	4	14
Corymorpha pendula (solitary hydroid)	0	0	0	0	0	1	2	0
Echinarachnius parma (sand dollar)								
Epitonium spp. (wentletraps)		2	1				1	2
Urctinia felina (northern red anemone)								5
Homarus americanus (american lobster)								
Crossaster papposus (spiny sunstar)							1	
Solaster endeca (purple sunstar)					1	4		2
Halichondria spp (Bread crumb sponges)								
Boltenia ovifera (stalked sea squirts)		1					6	11
Hippasteria phrygiana (horse star)	3	1	1	2	2	2	14	7

Table 4.4.1-6 Pigeon Hill Spring 2005 Fish & Invertebrate Video Observation Counts

Location	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Pigeon Hill	Santuary Hill
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
Video Drift #	1	2	3	4	5	6	7	8	9
Transect elapsed time (min)	1505	1500	1509	1951	1554	1503	1502	1501	1500
Transect Distance (meters)	340	311	356	312	174	123	110	198	221
Fish									
Macrozoarces americanus (ocean pout)									
Pseudopleuronectes americanus (winter flounder)									
Urophycis chuss (red hake)								1	
Myoxocephalus spp. (sculpin)			1	2					
Sebastes marinus (rosefish)		1		29	2			4	5
Raja spp. (skate)	1								
Pollachius virens (american pollock) (Large schools)		4		6				1	
Invertebrates									
Leptasterias tenera (sea star)	52	13	1	8	41	3		16	19
Cancer spp. (rock crab)									
Placopecten magellanicus (sea scallop)	1		3						
Myxicola infundibulum (slime worm)									
Solaster endeca (purple sunstar)	3								
Pagurus spp. (hermit crab)									
Cerianthus borealis (burrowing anemones)	1		5						
Corymorpha pendula (solitary hydroid)									
Echinarachnius parma (sand dollar)					3			8	
Epitonium spp. (wentletraps)					1				
Urctinia felina (northern red anemone)		2		1	8	1		3	2
Homarus americanus (american lobster)									
Crossaster papposus (spiny sunstar)	1	1		1			1		1
Solaster endeca (purple sunstar)		1	2		1		1		
Asterias vulgaris (northern sea star)			5		1				3
Halichondria spp (bread crumb sponges)		5		8	5	4	1	3	1
Boltenia ovifera (stalked sea squirts)	6	19	17	51	10	5	7	14	32
Hippasteria phrygiana (horse star)	3	23	14	24	9	2	5	9	7
Ectoprocta (encrusting bryozoan)		5		7		1			1
Terbratulina septentrionalis (brachipods)							6		
Hydrozoa (hydroids)		2		4				1	
Algae									
Crustose Algae (encrusting red algae observations)		1		4	8	4	1	1	
Rhodophyceae (branching red algae observations)		1		2	10	95% cover	Dense		

Table 4.4.1-7 Stellwagen Fall 2004 Fish & Invertebrate Video Observation Counts

Location	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen
Season	Fall	Fall	Fall	Fall	Fall	Fall	Fall	Fall	Fall
Video Drift #	1	2	3	4	5	6	7	8	9
Transect elapsed time (min)	1500	2727	1531	1528	1509	1530	1516	0650	1440
Transect distance (meters)	370	764	500	456	466	756	573	271	477
Fish									
Macrozoarces americanus (ocean pout)		2			1	2			
Pseudopleuronectes americanus (winter flounder)		1	2	2	1		5		
Urophycis chuss (red hake)	4	6	8	1	6	12	1		3
Juvenile Myoxocephalus spp. (sculpin)						2	2		2
Myoxocephalus spp. (sculpin)		3	2		2		2		
Sebastes marinus (rosefish)								1	
Invertebrates									
Leptasterias tenera (sea star)	80	148	167			203	10	7	3
Crangon spp. (shrimp)				6	2	2			
Cancer spp. (rock crab)				1	2	6	1		
Loligo pealei (squid)			1						
Placopecten magellanicus (sea scallop)			1				2		3
Myxicola infundibulum (slime worm)									
Pagurus spp. (hermit crab)								1	
Cerianthus borealis (burrowing anemones)		259	268			2	118	11	62
Corymorpha pendula (solitary hydroid)									
Echinarachnius parma (sand dollar)									
Epitonium spp. (wentletraps)									
Urctinia felina (northern red anemone)								1	
Homarus americanus (american lobster)	1								
Crossaster papposus (spiny sunstar)								1	
Solaster endeca (purple sunstar)									
Asterias vulgaris (northern sea star)	2		2			7	10		2
Halichondria spp (bread crumb sponges)		20	5					2	
Boltenia ovifera (stalked sea squirts)									
Hippasteria phrygiana (horse star)									
Ectoprocta (encrusting bryozoans)									
Terbratulina septentrionalis (brachipods)									
Hydrozoa (hydroids)									

Table 4.4.1-8 Stellwagen Spring 2005 Fish & Invertebrate Video Observation Counts

Location	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen	Stellwagen
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
Video Drift #	1	2	3	4	5	6	7	8
Transect elapsed time (min)	1459	1459	1459	1459	1459	1459	1459	1459
Transect distance (meters)	444	384	260	280	267	220	160	156
Fish								
Macrozoarces americanus (ocean pout)			1		2			
Pseudopleuronectes americanus (winter flounder)								
Urophycis chuss (red hake)			4					
Myoxocephalus spp. (sculpin)				1		1		
Sebastes marinus (rosefish)								1
Invertebrates								
Leptasterias tenera (sea star)	91	15	88	33		24	9	8
Crangon spp. (shrimp)								
Cancer spp. (rock crab)								
Loligo pealei (s quid)								
Modiolus modiolus (horse mussels)							1	
Psolus fabricii (sea cucumber*)*							1	
Placopecten magellanicus (sea scallop)	1	1				1		
Myxicola infundibulum (slime worm)								
Solaster endeca (purple sunstar)	2							
Cerianthus borealis (burrowing anemones)	149	209			2		4	26
Corymorpha pendula (solitary hydroid)								
Echinarachnius parma (sand dollar)								
Epitonium spp. (wentletraps)								
Urctinia felina (northern red anemone)				2	3	2	1	3
Homarus americanus (american lobster)			1					
Crossaster papposus (spiny sunstar)							4	2
Solaster endeca (purple sunstar)		2		3			1	1
Asterias vulgaris (northern sea star)	1		2	1	2	5	1	4
Halichondria spp (bread crumb sponges)		1		5	7	6	7	7
Boltenia ovifera (stalked sea squirt)					2	2		
Hippasteria phrygiana (Horse star)			7					1
Ectoprocta (encrusting bryozoans)				1	3	4		4
Terbratulina septentrionalis (brachipods)								
Hydrozoa (hydroids)				3	3	2	4	1

higher than those observed on the *fall* 2004 EFH video sled surveys of similar duration, depth and sandy/mud bottom habitats.

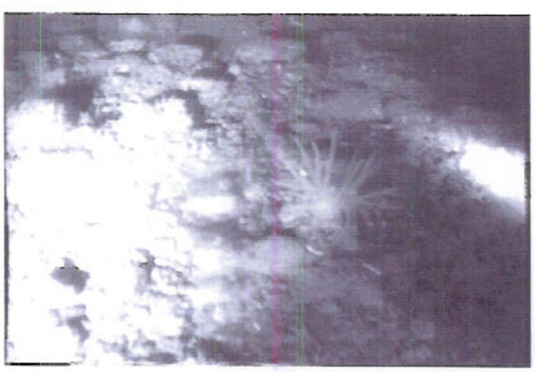
In summary, at Pigeon Hills and Stellwagen/Long Bank study sites, a wide variety of bottom habitats were observed ranging from simple flat sand bottom (Category 1) to complex rock ledge and piled bolder bottom habitat (Category 8). These areas have historically been productive fishing sites. However, with the exception of several large schools of juvenile pollock that were observed on the *spring* Pigeon Hills video survey, very few fish were observed during the study. As reported by the local fishermen, the fish catches at these sites can be highly seasonal and affected by water temperature and the presence of certain prey items. Historic site productivity may be due in part to the diverse bottom habitat present at these sites, but there are numerous other oceanographic factors such as temperature, chlorophyll levels and upwelling that may influence the productivity of these areas.

4.4.2 DRIFT CAMERA OBSERVATIONS

Drift camera deployments were started in the fall of 2004 when it was anticipated that the CR video sled equipment could not be used in areas of high relief due to the possibility of damage to the equipment. With the incorporation of a variable flow hydraulic control it was then possible to use the sled in areas of boulders and rock ledge. The drift camera was however used at both sites in the fall of 2004 and the spring of 2005 to increase area coverage and possibly identify habitat types that might not have been found in the sled surveys.

Significant problems with the use of the drift camera included the fact that it had to be of low weight in order to be manually raised and lowered and thus was very susceptible to the strong currents found at both sites. It was therefore very difficult to keep the camera close to the bottom throughout a drift. In addition, the incandescent lights produced a focused point of light, which limited the field of vision. Black and white photography limited species identification. The system was used mostly as a back-up and approximately 20 hours of videos were obtained. There were no habitat types seen in these drifts that were not also found in the video sled tows. The quality of the screen captures from the CR sled cameras was much higher and thus are the only ones included in the report. Plate 4.4.2 includes some representative screen captures of habitat types from the drift videos.

PLATE 4.4.2 SCREEN CAPTURES FROM DRIFT VIDEOS (HABITAT)



4.4.3 ROV OBSERVATIONS

The TITAN mini-ROV was of limited use primarily due to its size and tether length (100 m). It could not be successfully deployed in the deeper parts of the study areas and currents in the shallow areas, and the presence of fixed gear, limited its use. The only successful deployment was at the northeastern region of West Pigeon Hill in the spring of 2005 during a slack tide. In that case, habitat changed from a cobble/boulder bottom at 60 m, up through clean rock face and back to cobble bottom in a very short distance (10's of meters). Large schools of small pollock (100s), also seen in video sled tows, were observed.

4.4.4 BAITED VIDEO

The baited video system, which had been built for and used successfully in near shore studies in shallow water, was of very limited use on this project despite numerous deployments. At the deeper sites lighting was an issue and surface currents were a significant problem for the buoy. In several cases the electrical umbilical cord from the camera to the surface buoy became detached during the period of operation.

There were only two deployments when fish were recorded on the video, both in the spring of 2005. In the first, the camera and buoy system was set on the top of West Pigeon Hill at a depth of 35 m for two hours. The resultant video showed a large school of pollock approximately half way through the recording time and a total of 5 additional small, unidentified fish at other times. At the Stellwagen site, the system was deployed for nine hours at 62 m depth at the eastern edge of Long Bank. That video recorded a total of 9 sculpins and, at the end, a large school (>20) pollock. All other deployments produced no fish sightings.

PLATE 4.4.4 SCREEN CAPTURE FROM BAITED VIDEO

4.6 CTD PROFILES

Deployments of the Seacat profiler for both the Pigeon Hills and the Stellwagen/Long bank sites are shown in Figures 4.5.1 and 4.5.2. Representative profiles taken during the initial surveys are in Figures 4.5.3 (Pigeon Hills) and 4.5.4 (Stellwagen/Long Bank). Additional profiles are included in Appendix D.

Profiles from the Pigeon Hills region in early August show a very strong thermocline with surface temperatures around 17° C, decreasing to from 6 to 8.5° C at 20 m depth. Bottom temperature at the deeper stations (>40 m) was 5.3° C. There were noticeable differences in the slope of the thermocline, probably due to currents (both tidal and long term) or internal waves. Salinity increased slightly from 31.6 ppt at the surface to 32.4 ppt at depth (Station C1).

Water column profiles from the Stellwagen/Long Bank transect were of a very similar structure to those seen at Pigeon Hills. Surface temperatures were approximately 17° C decreasing to from 8 to 10.5° C at 20 m depth, depending on the structure of the thermocline. At 40 meters depth, the temperature dropped to 5.5° C with only a slight decrease below 5 degrees at the deepest site (66 meters)

In late September at the Pigeon Hills site, a strong thermocline was still present (Figure 4.5.5). At station C1, the temperature from the surface to 12 m depth was very consistent at approximately 16° C. From 15 m to 30 m the temperature dropped to 10° C. Station C4 was almost uniform in temperature from the surface to a depth of more than 20 m. Other profiles such as those from C2, C3 and C5 had a more gradual decline in temperature through the water column. Bottom temperatures at deep sites of 60 m or more were 7.3° C. These stations were located within relatively short distances of each other which highlights the complexity of the water column structure around rock outcrops. In all cases there was a slight increase in salinity from the surface to the bottom. A very sharp spike in fluorescence was associated with the thermocline at all sites. This is typical of the regional waters at this time of year when dead or dying phytoplankton accumulate along the density differences associated with the pycnocline.

By November, the water column was no longer stratified and temperatures were fairly uniform around 8 to 8.5° C from surface to bottom (Figure 4.5.5, Pigeon Hills). There was a very slight increase in salinity from 32.25 ppt at the surface to 32.35 ppt at depth.

Profiles from the Stellwagen/Long Bank site for May (Figure 4.5.6) show the early development of a thermocline (Figure 4.5.6). Surface temperature was 8.2° C with a decrease to 4.5° C at approximately 10 m depth and a slight further reduction to 3.5° C at depths below 30 meters. The influence of spring runoff was seen in the salinity profiles. There was an increase from 29 ppt at the surface to 31 ppt at 10 m depth and an additional gradual increase to 32 ppt below 30 m.

FIGURE 4.5.1 CTD PROFILE STATIONS, PIGEON HILLS SITE

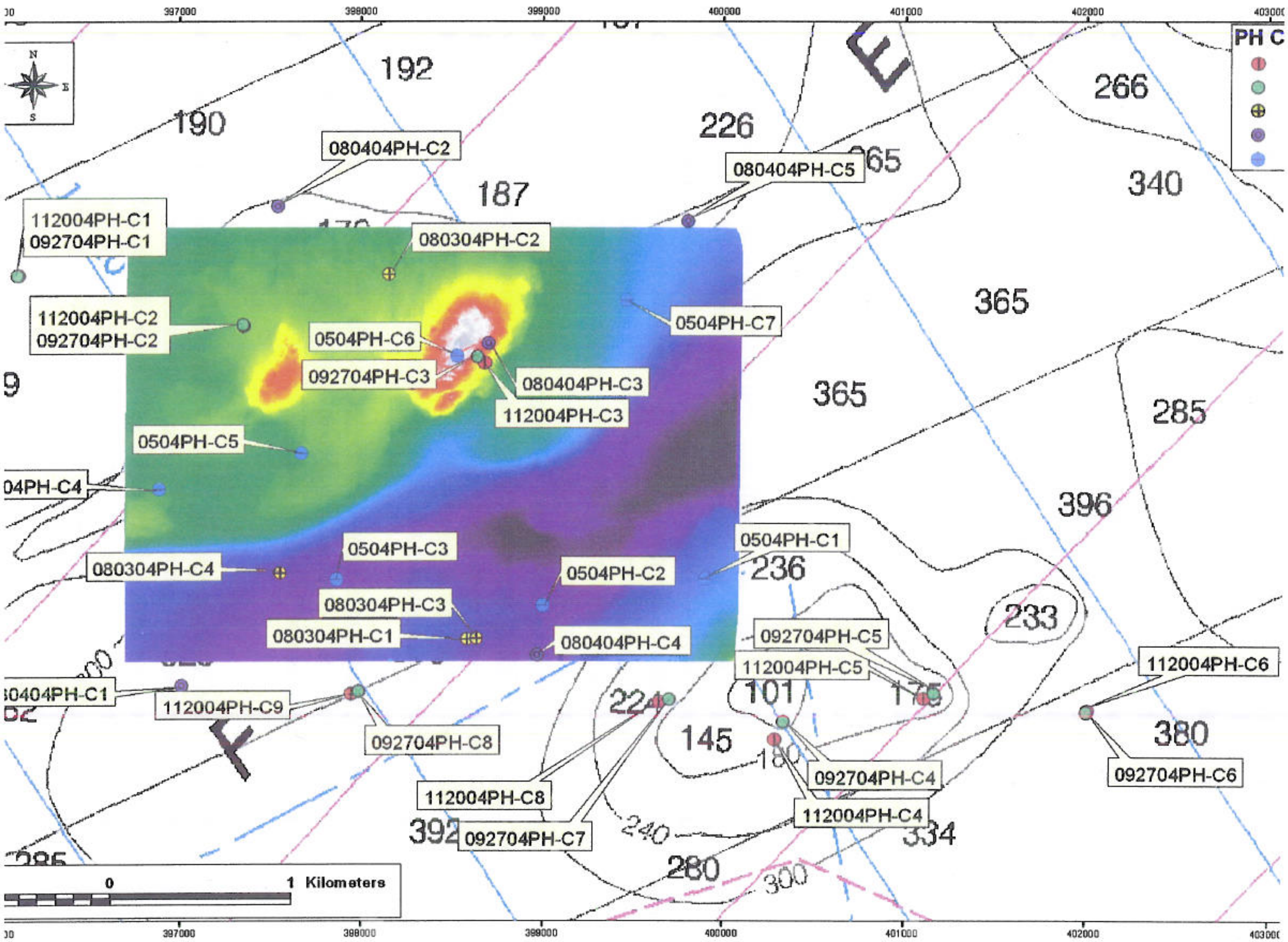


FIGURE 4.5.2 CTD PROFILE STATIONS, STELLWAGEN/LONG BANK SITE

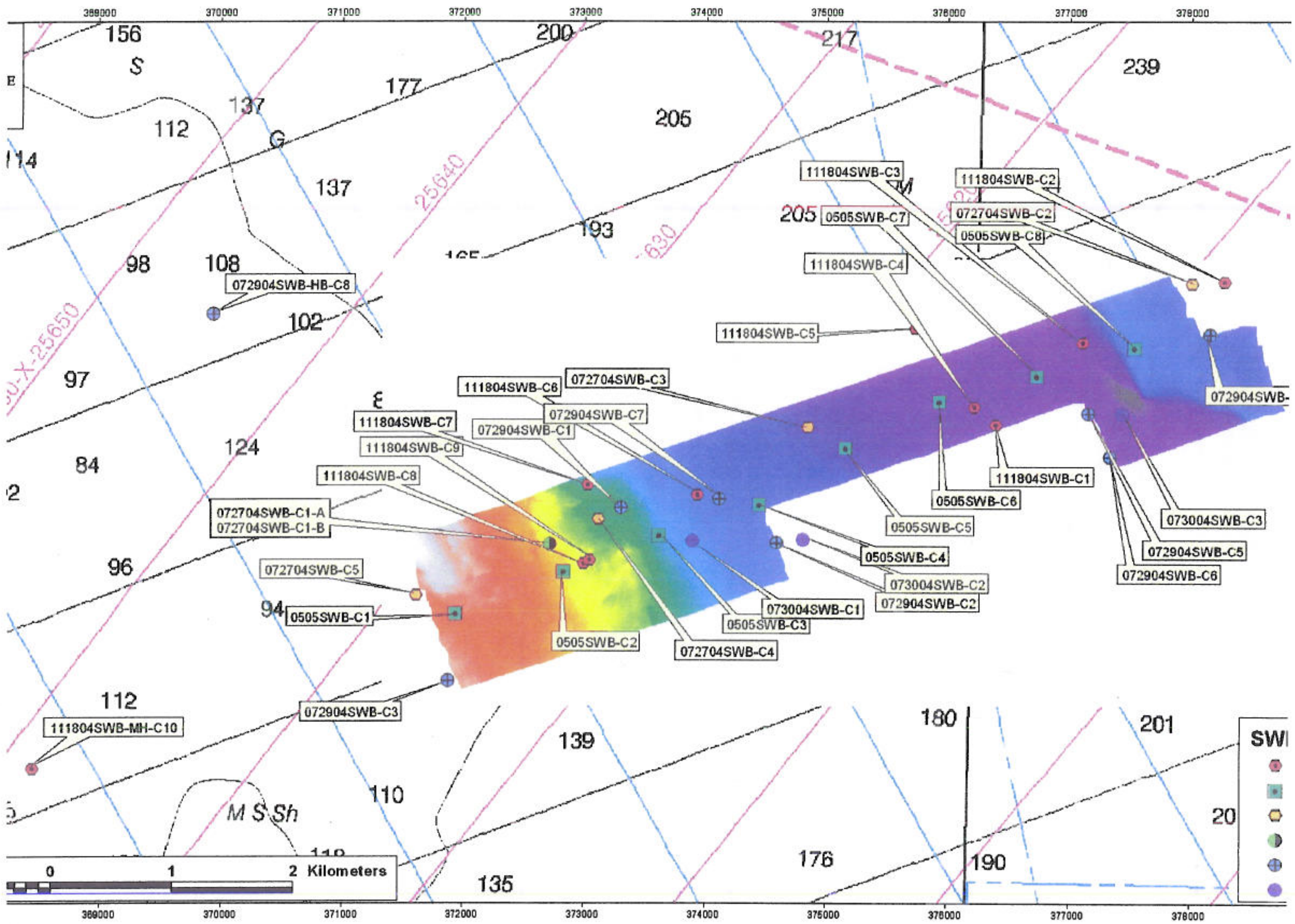
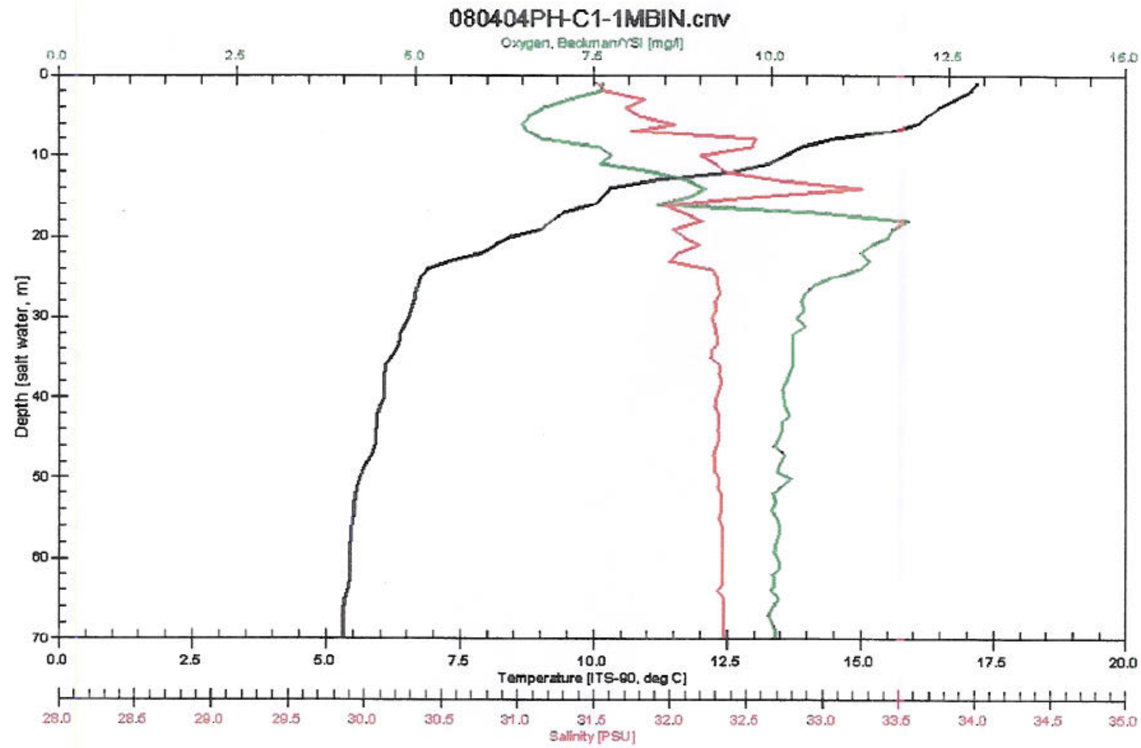
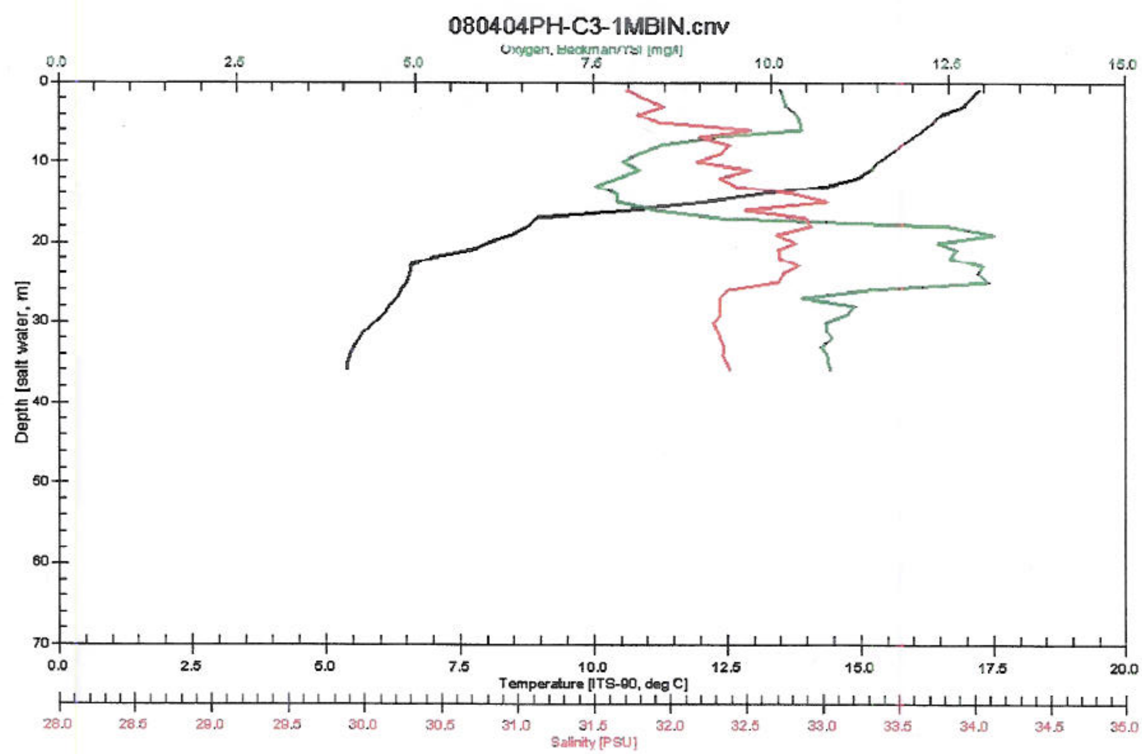
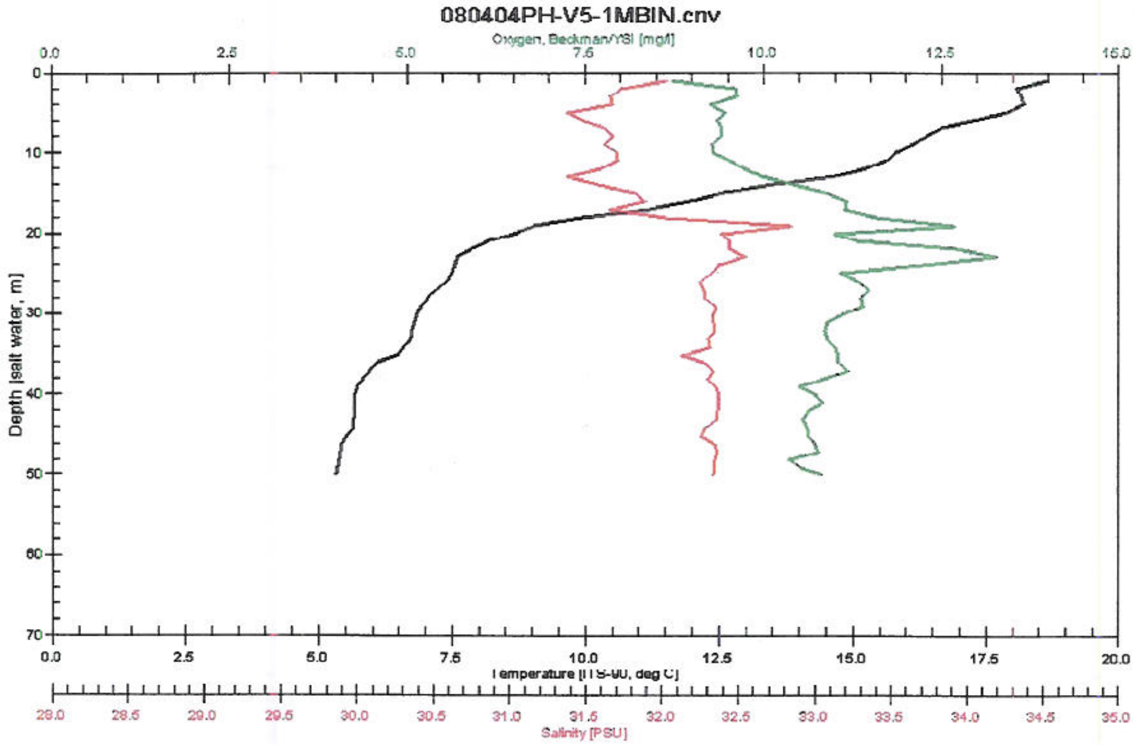


Figure 4.5.3. Pigeon Hills Profiles August 2004






080404PH-V5-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0

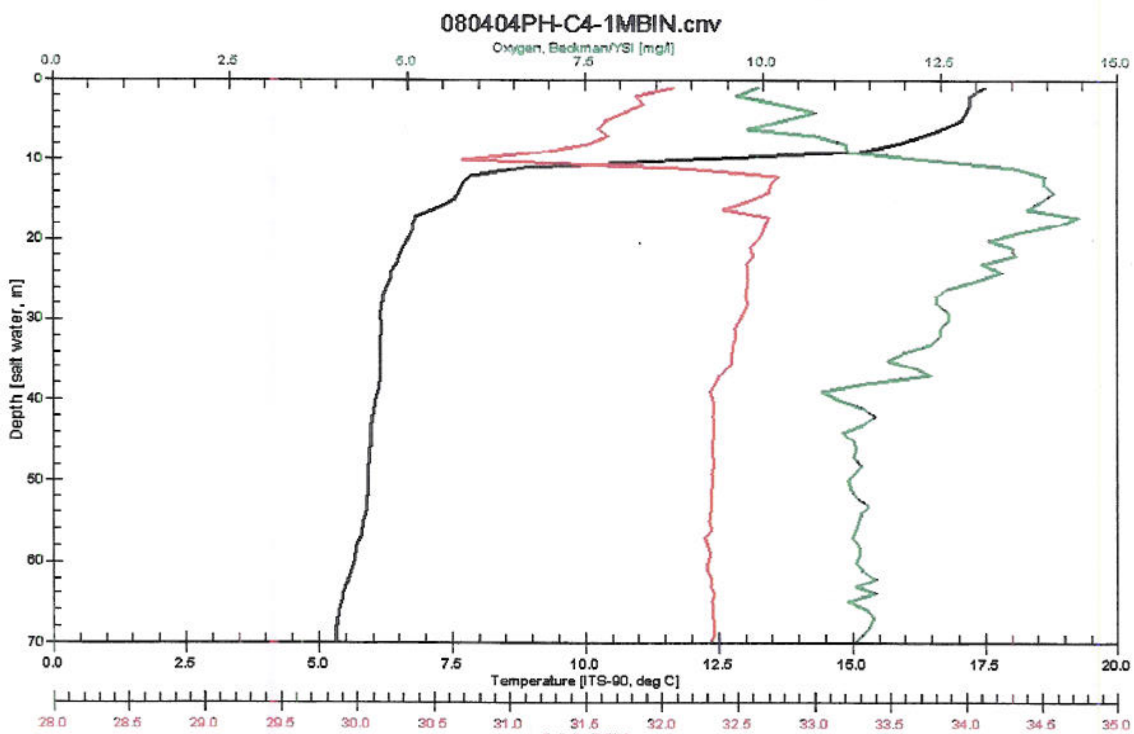
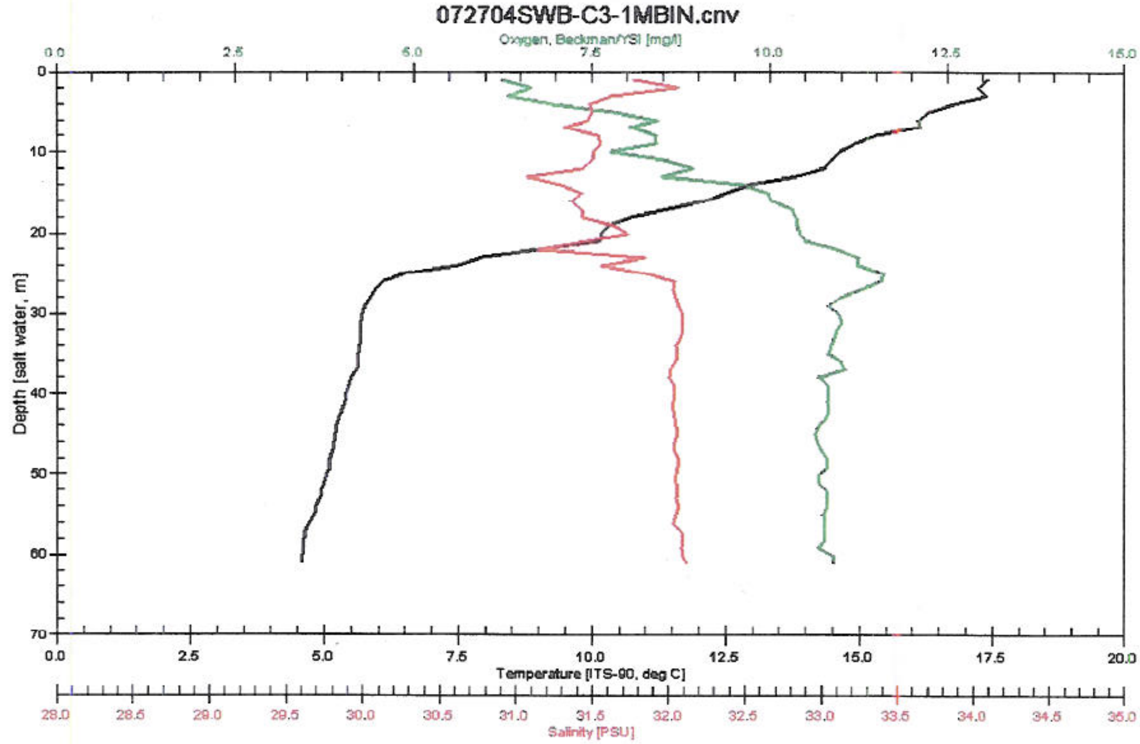
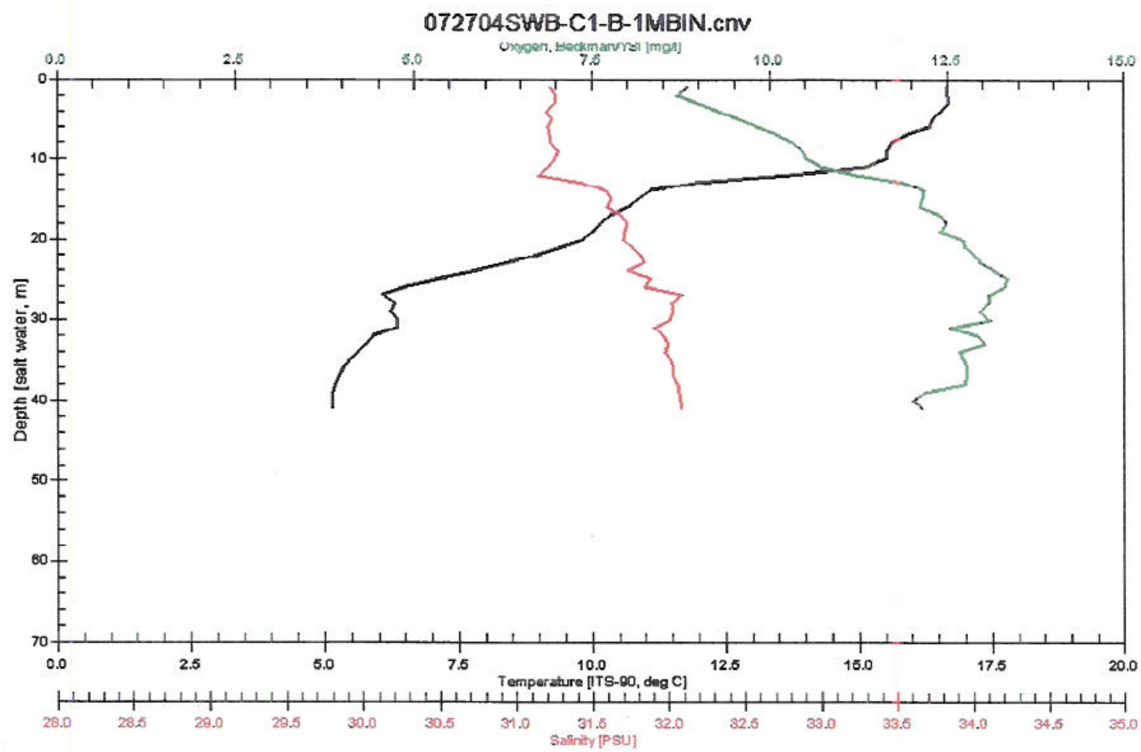
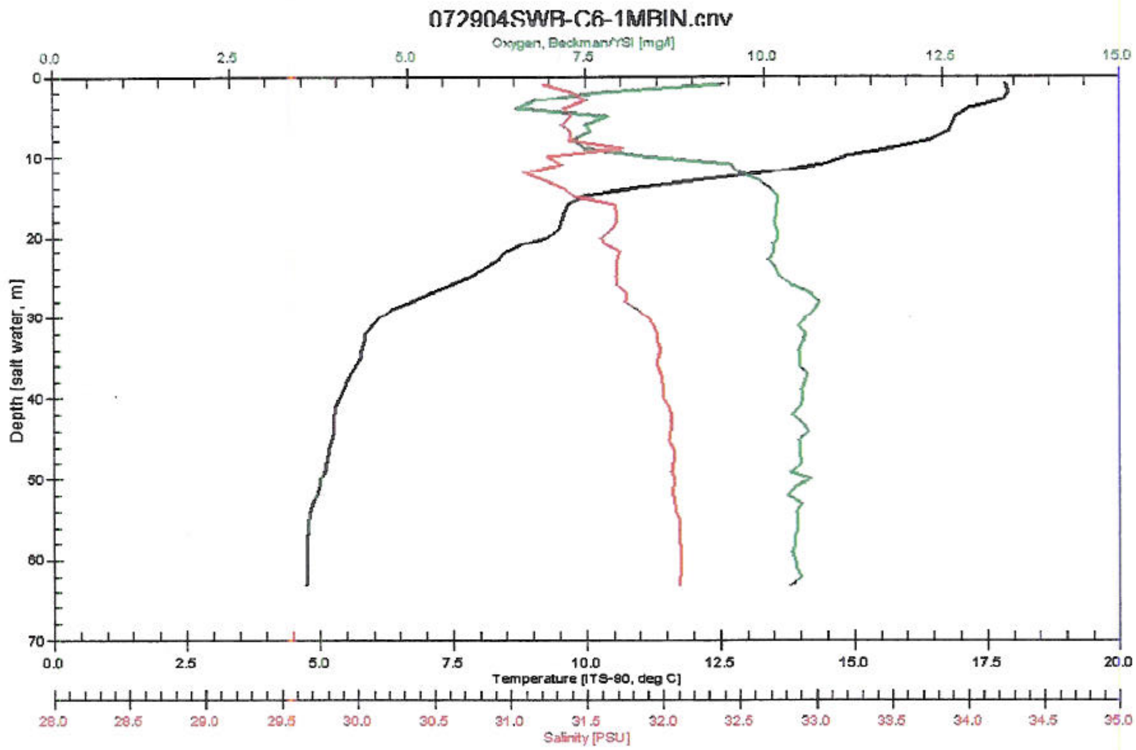

080404PH-C4-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0

Figure 4.5.4. Stellwagen-Long Bank Profiles July 2004






072904SWB-C6-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Salinity [PSU]

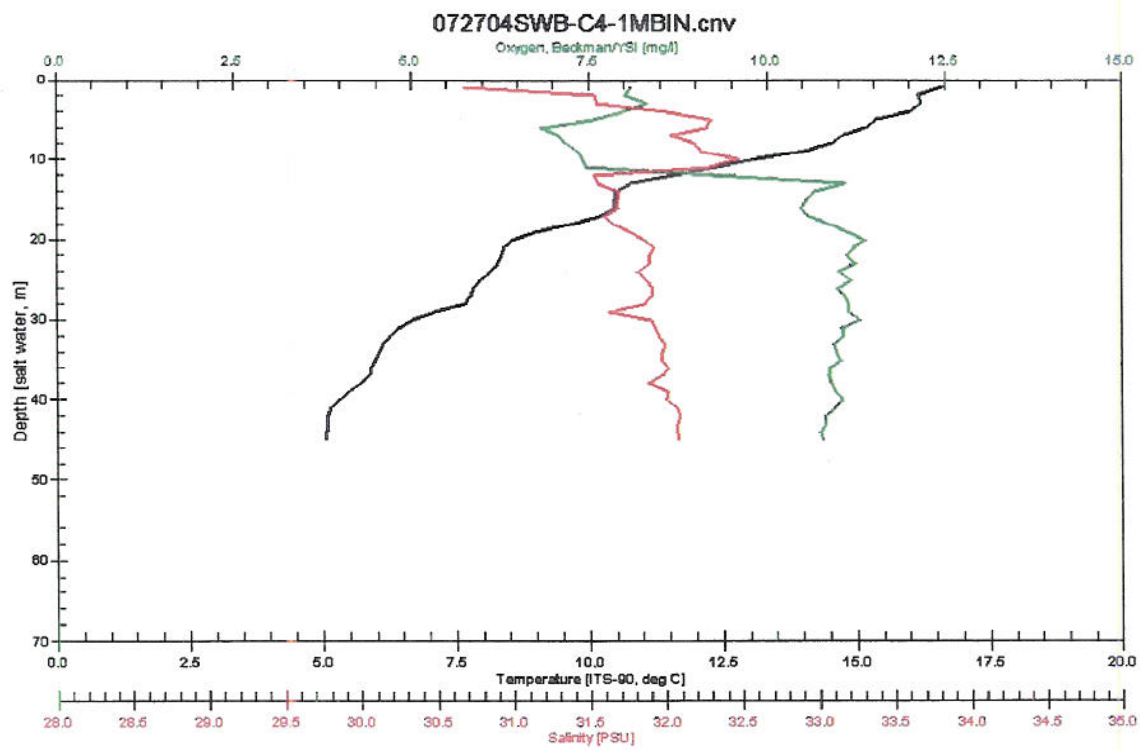
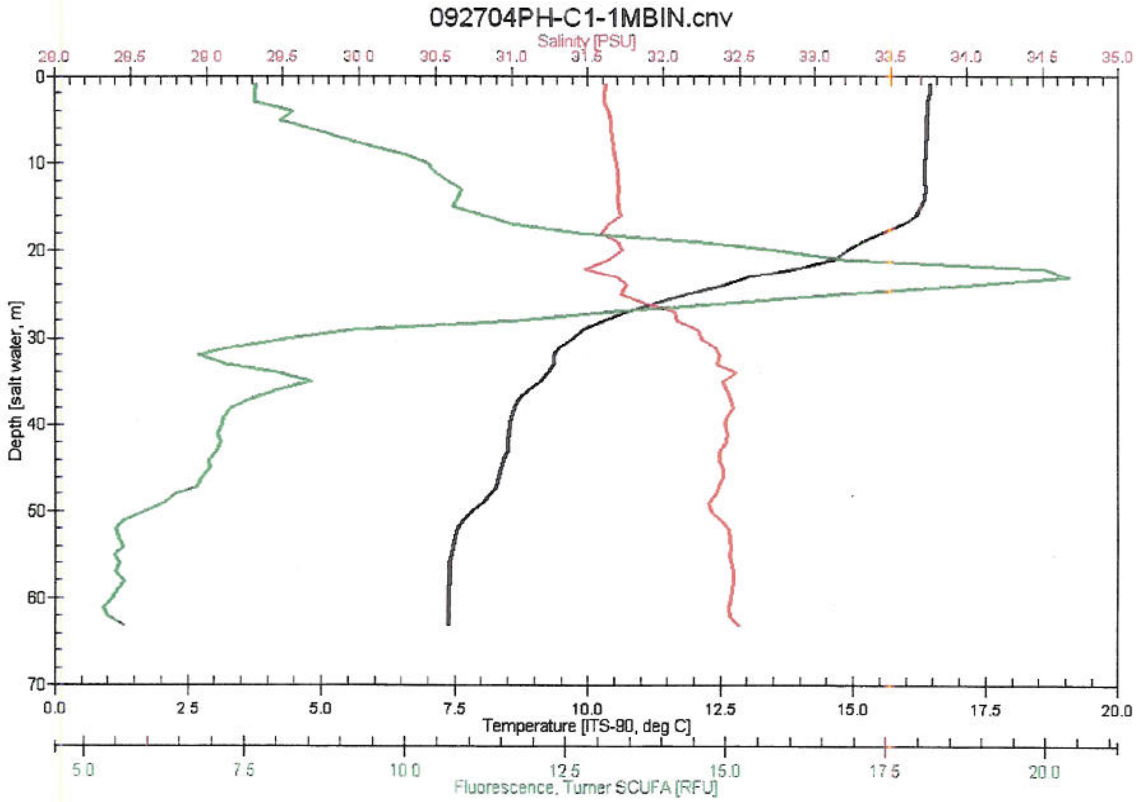
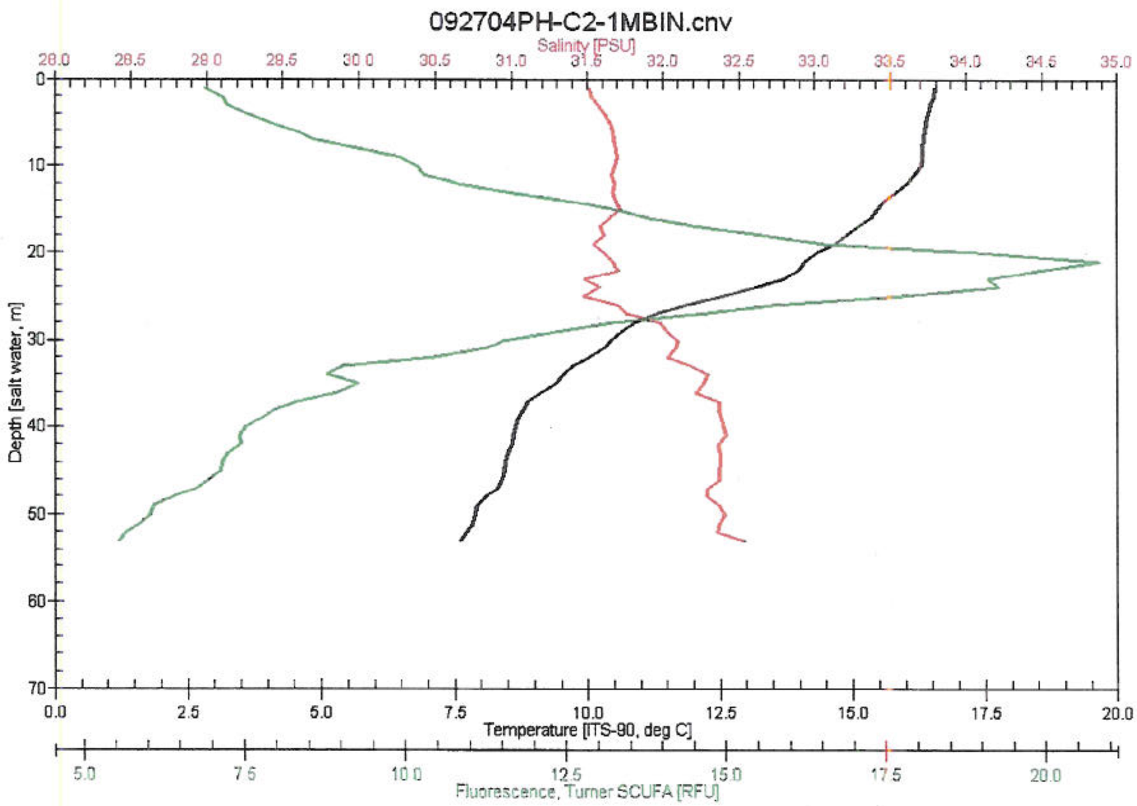
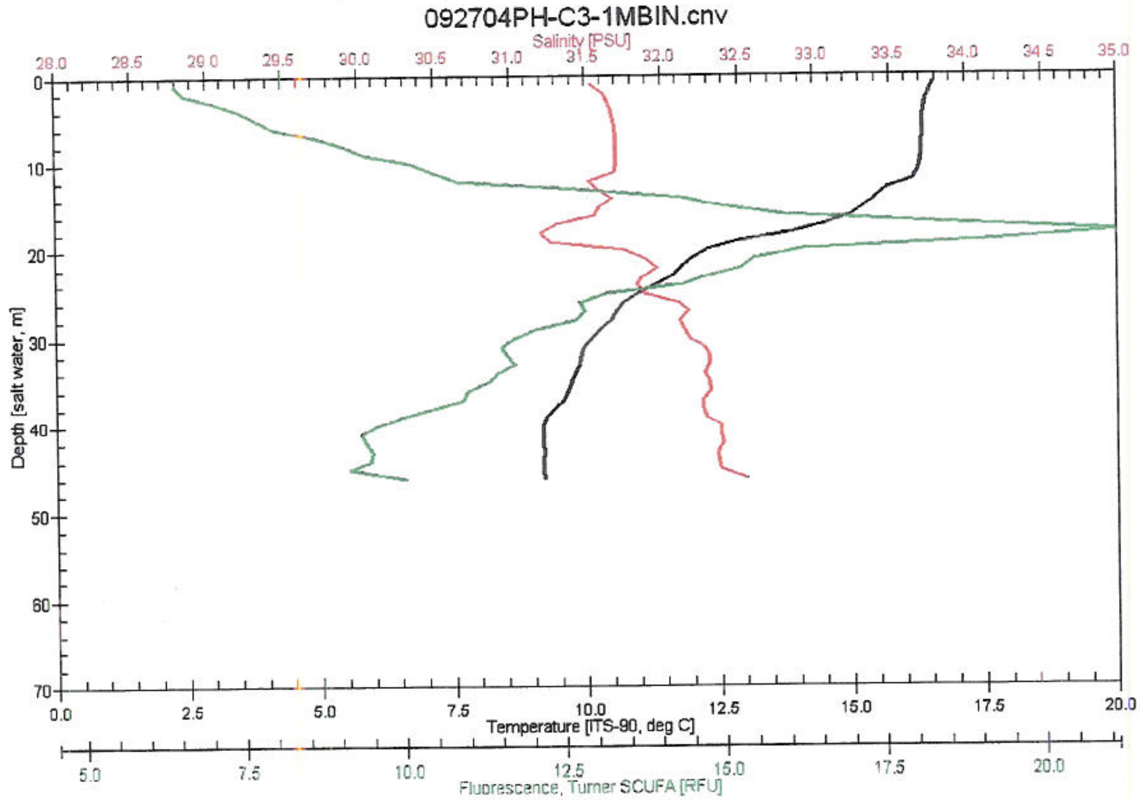
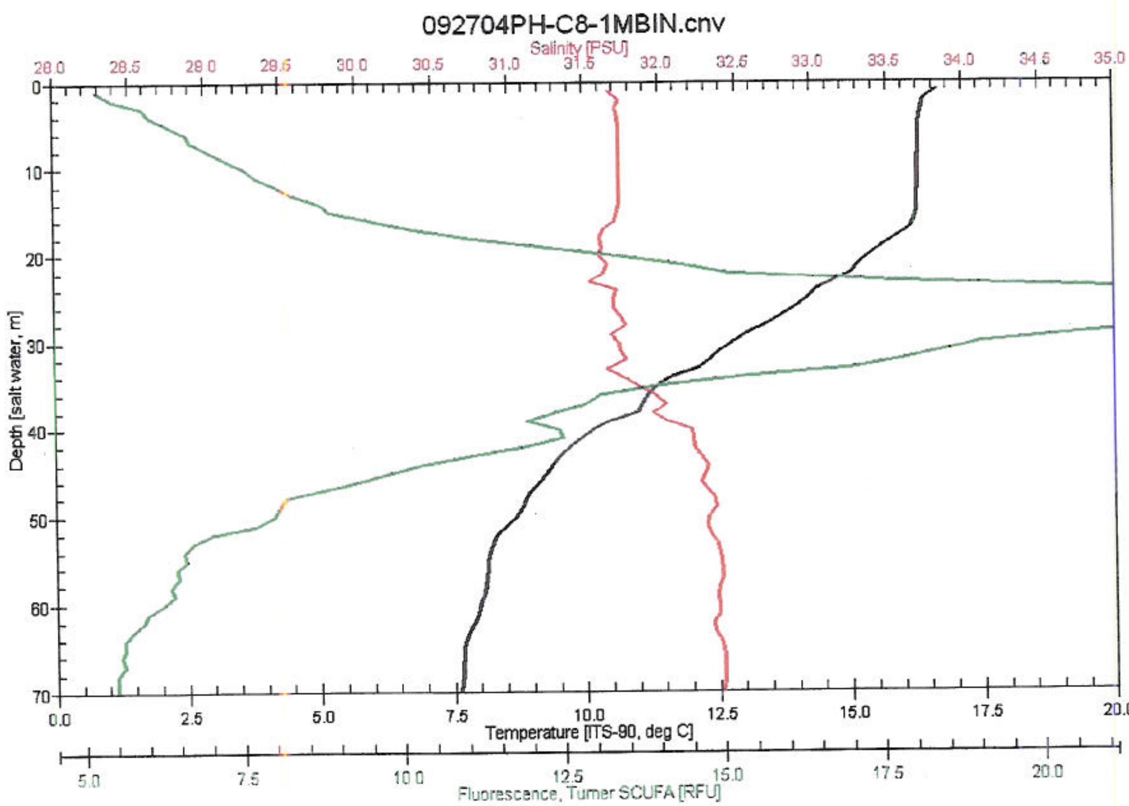

072704SWB-C4-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Salinity [PSU]

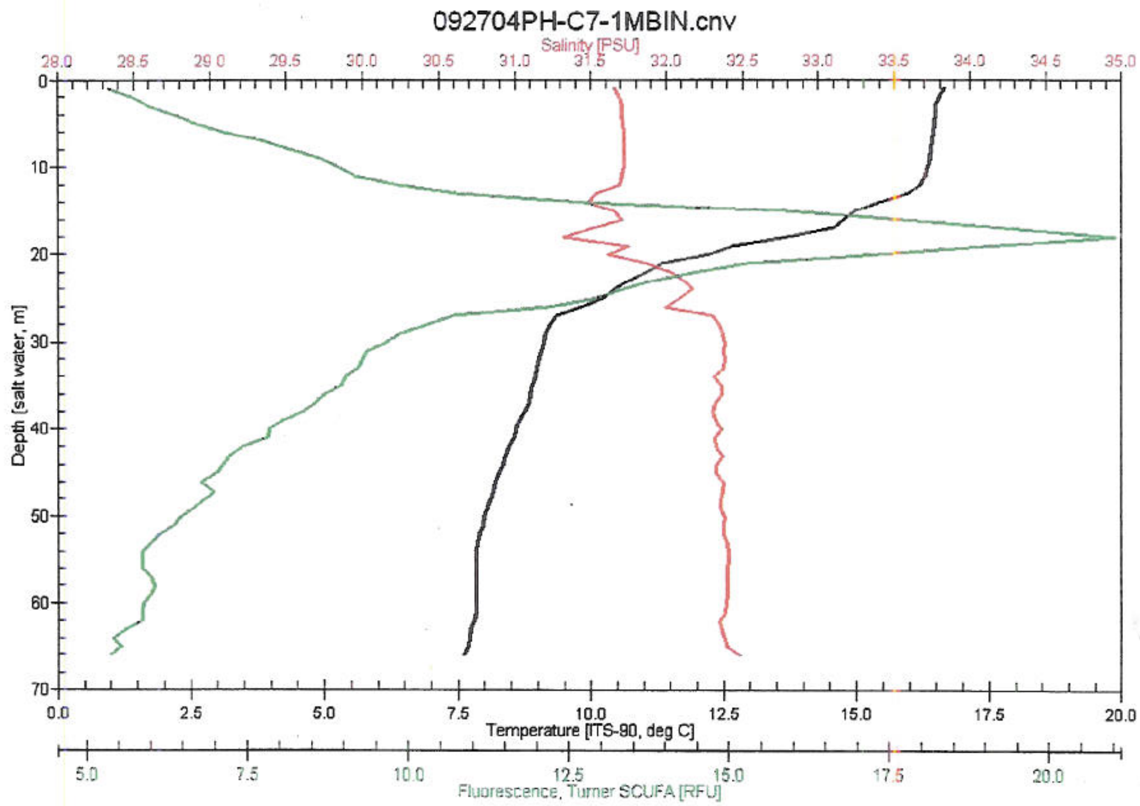
Figure 4.5.5. Profiles Pigeon Hills September

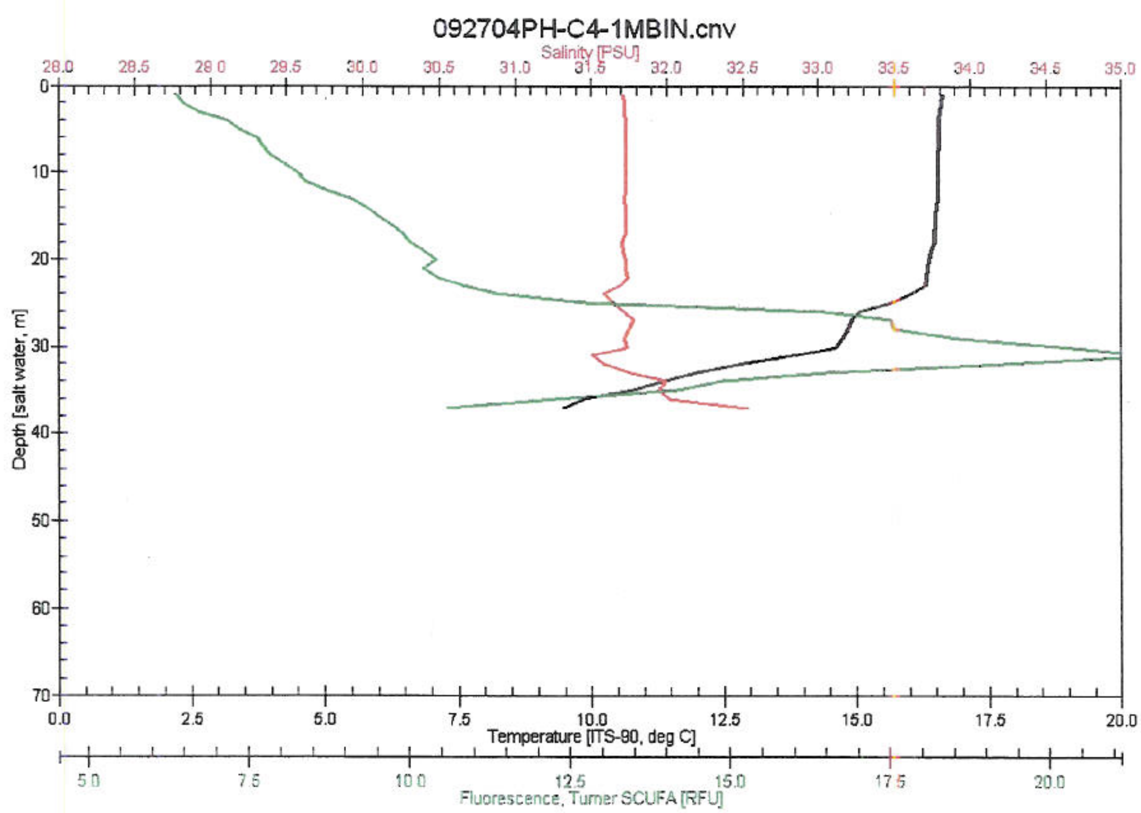


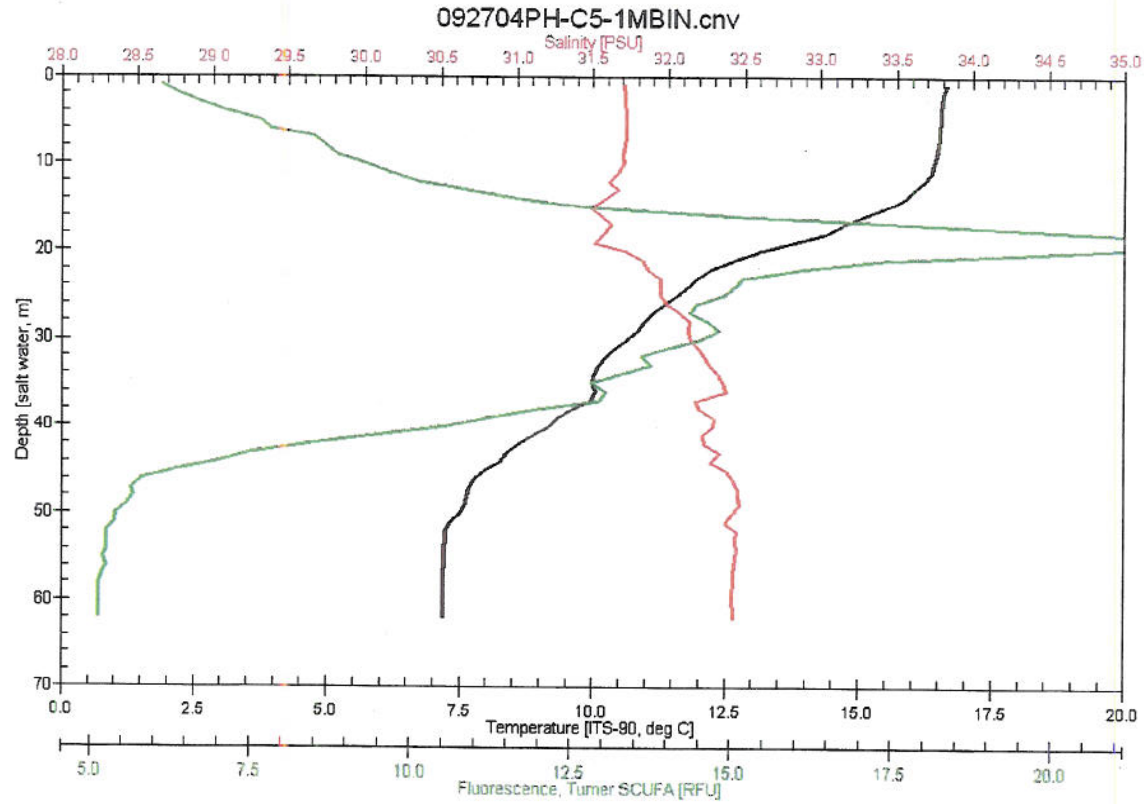



092704PH-C3-1MBIN.cnv
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Fluorescence, Turner SCUFA [RFU]
5.0
7.5
10.0
12.5
15.0
17.5
20.0


092704PH-C8-1MBIN.cnv
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Fluorescence, Turner SCUFA [RFU]
5.0
7.5
10.0
12.5
15.0
17.5
20.0


092704PH-C7-1MBIN.cnv
Salinity [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]


092704PH-C4-1MBIN.cnv
Salinity [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]


092704PH-C5-1MBIN.cnv
Salinity [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]

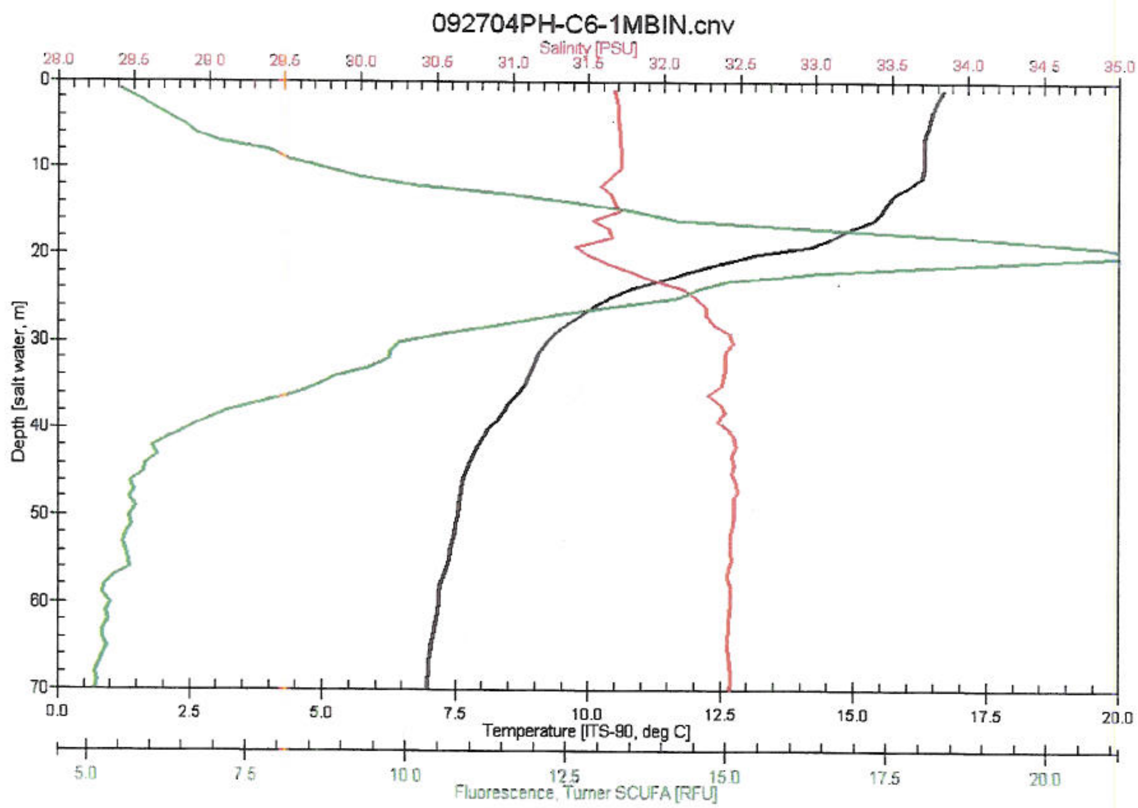
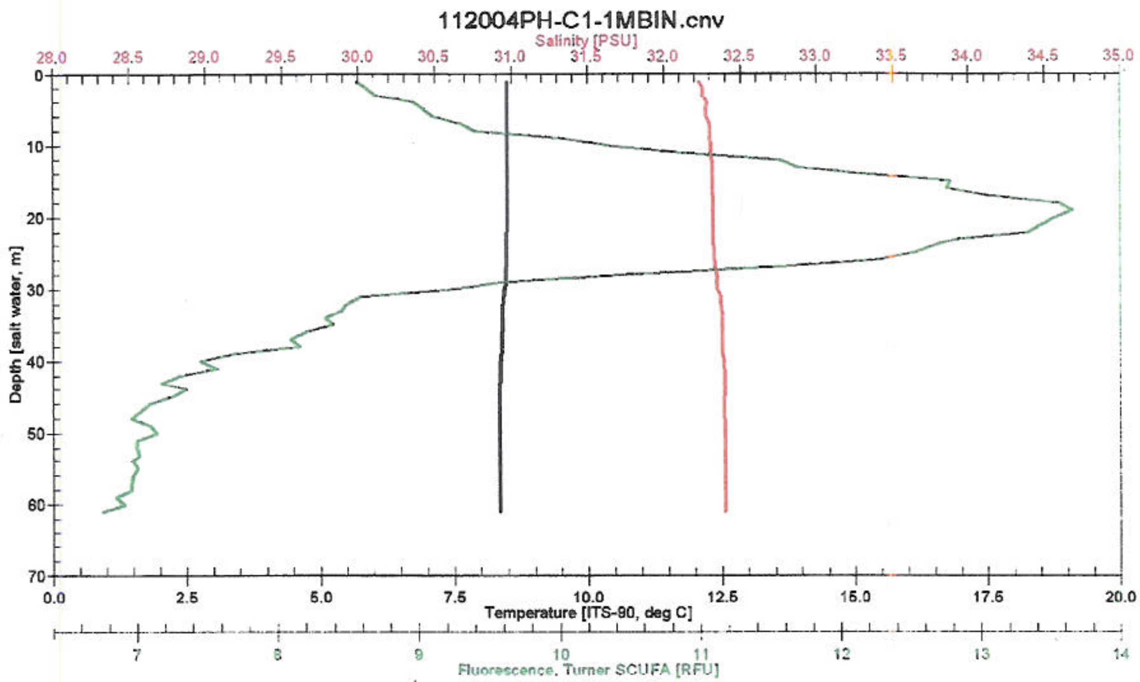
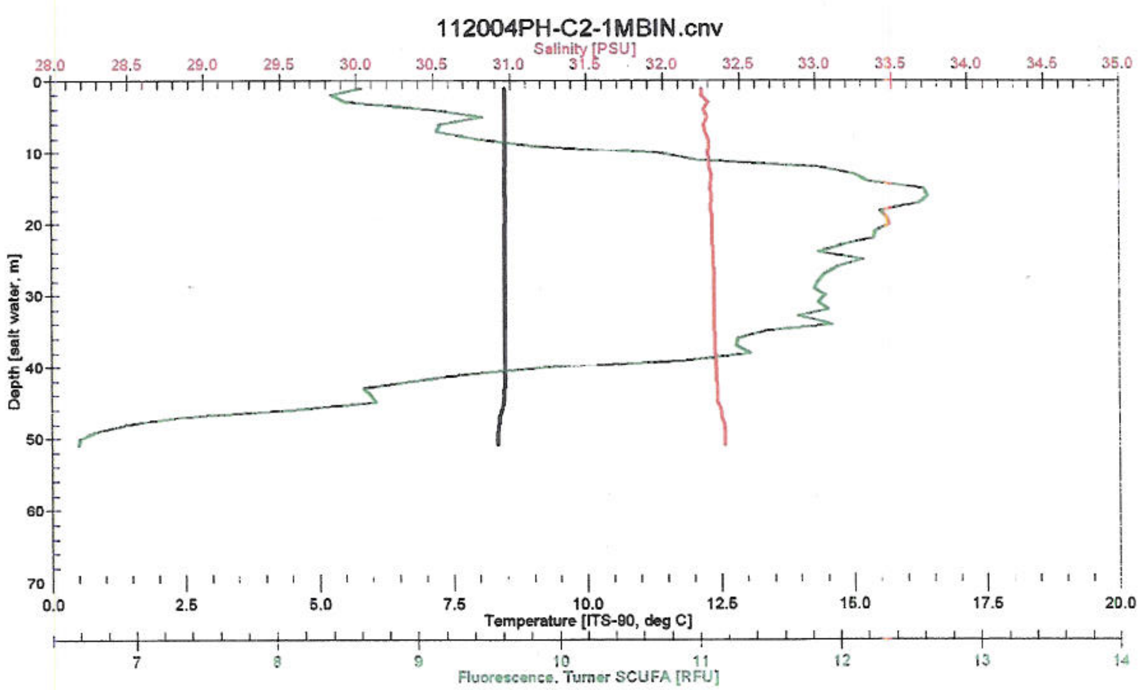
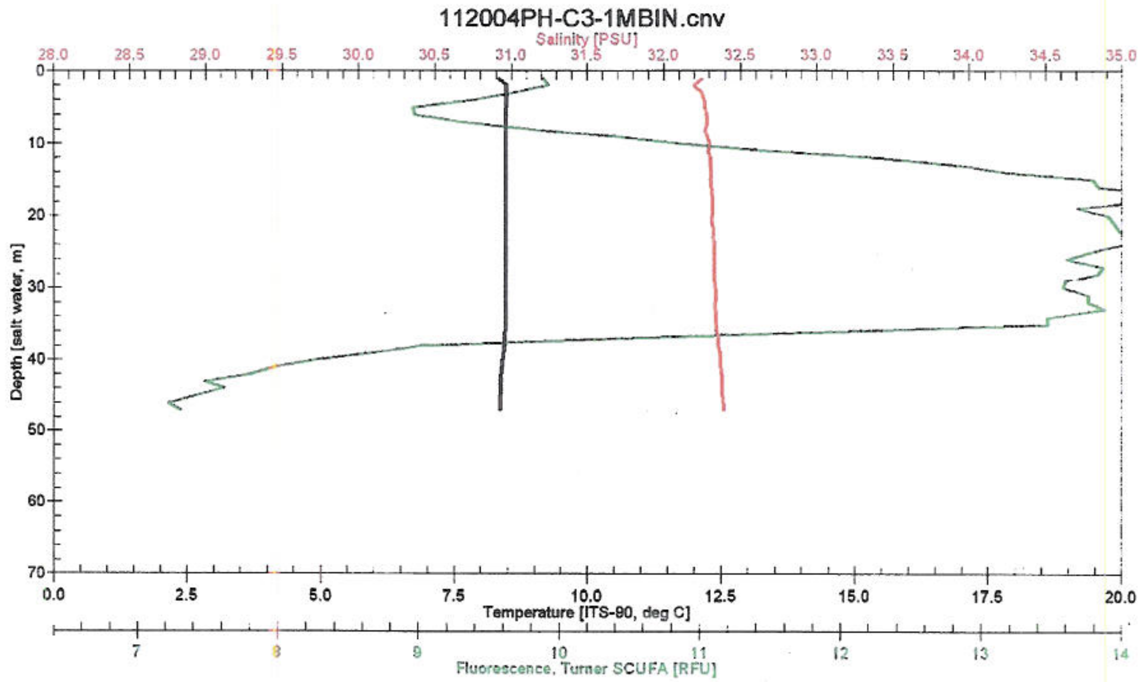

092704PH-C6-1MBIN.cnv
Salinity [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]

Figure 4.5.6. Pigeon Hills Profiles November 2004






112004PH-C3-1MBIN.cnv
Salinity [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]

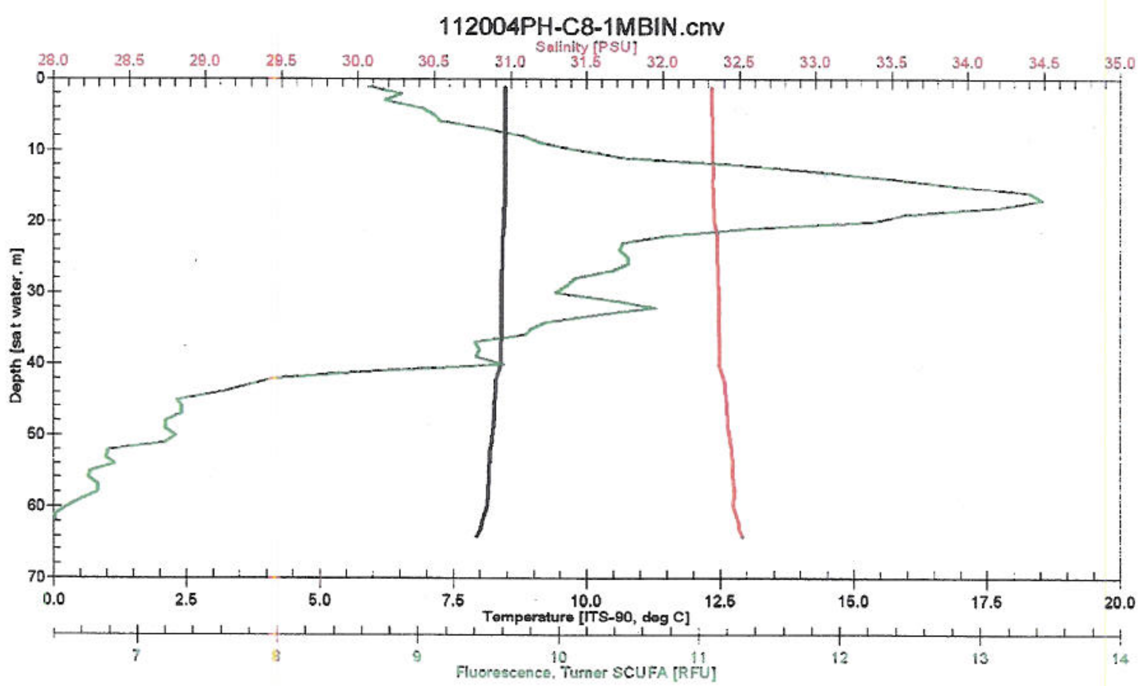
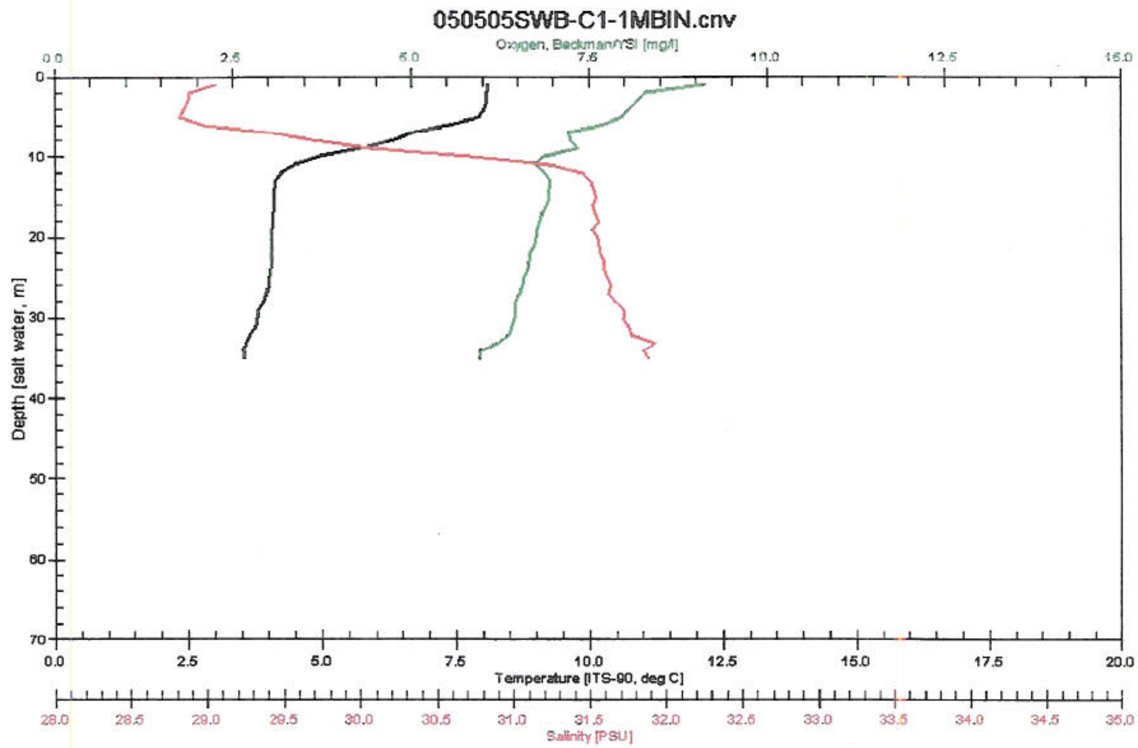
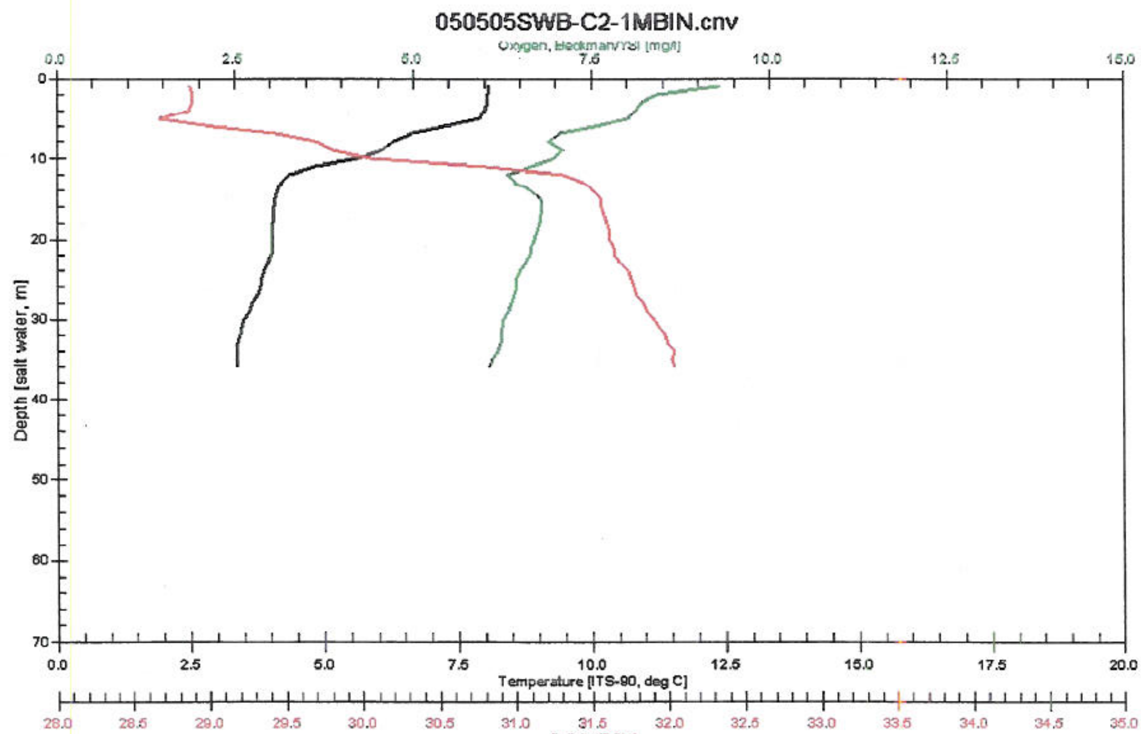
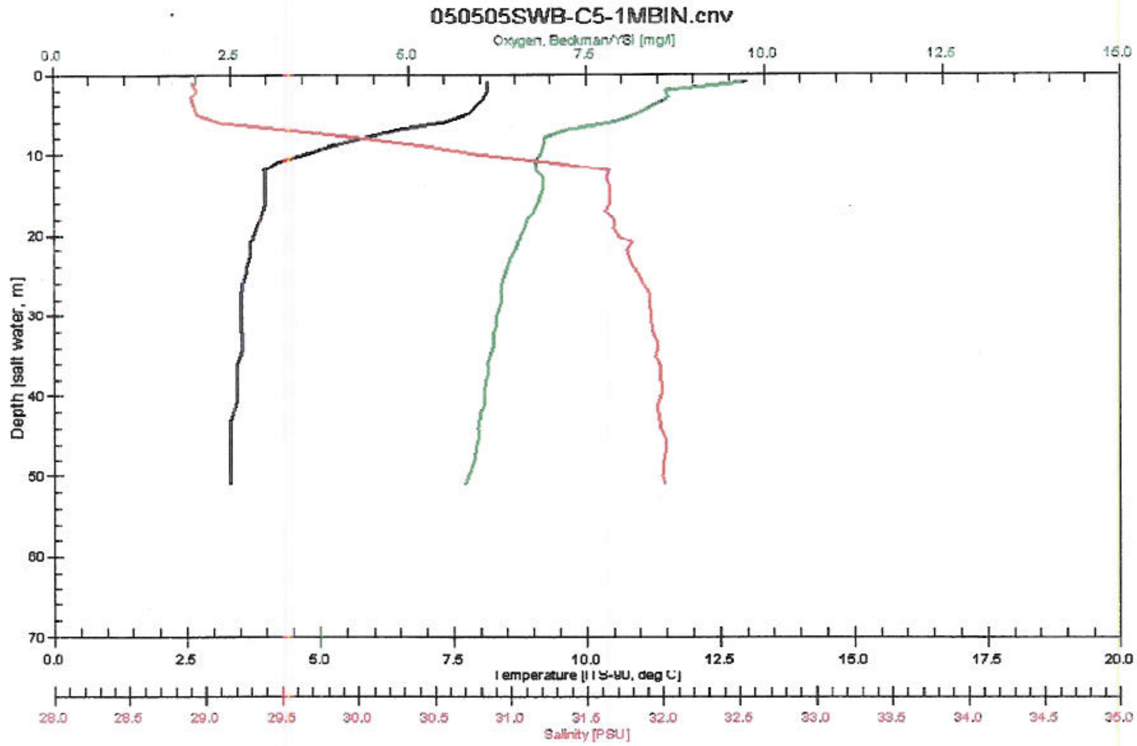
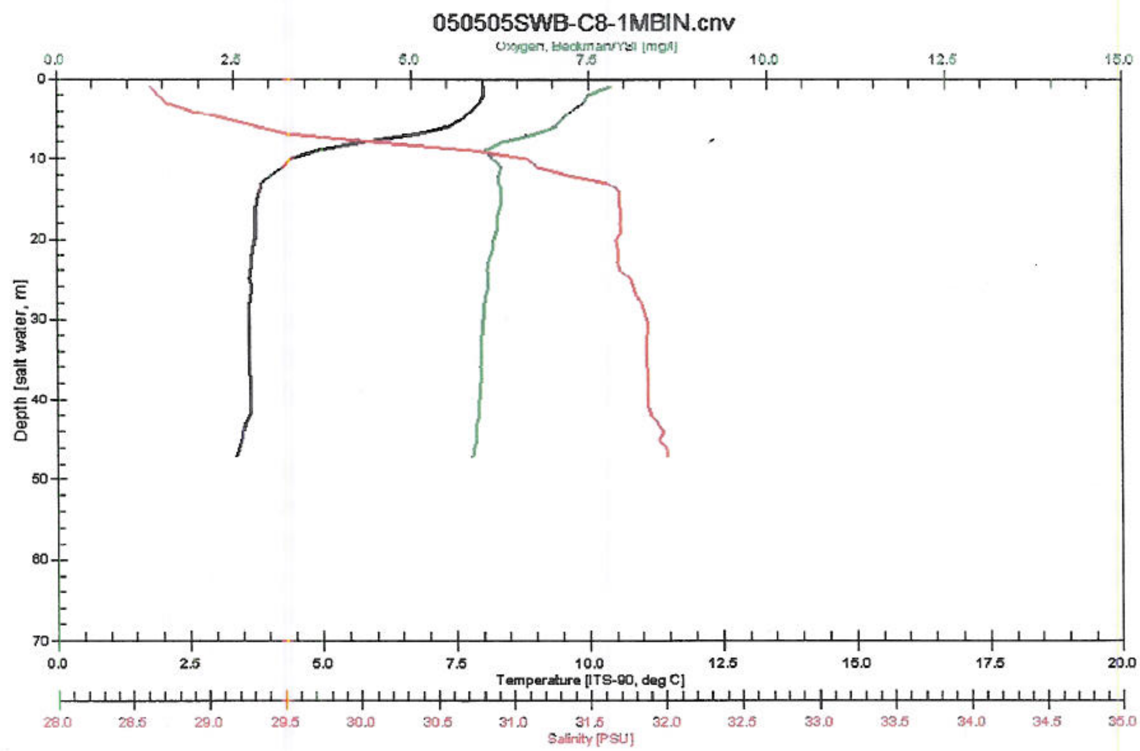

112004PH-C8-1MBIN.cnv
Salinity [PSU]
Depth [salt water, m]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]

Figure 4.5.7. Stellwagen-Long Bank Profiles May 2005






050505SWB-C5-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0


050505SWB-C8-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0

4.6 SOFT BOTTOM BENTHOS

4.6.1 BENTHIC INFAUNA

More than 200 species of benthic invertebrates were identified in the samples. There were 126 species of polychaetes, 23 species of amphipods, 19 species of bivalves, 10 gastropods and seven echinoderms. Complete results for all replicates are included in the Appendix. Table 4.6.1 lists the dominant species based on the combined three replicates at each site. Three replicate grab samples collected from 76 (Station SB2) to 104 species (SB7). The number of individuals ranged from 1,822 (SB2) to 3,562 (SB5). This represents faunal densities of from 15,177 to 29,671 organisms per square meter. There was a correlation between the diversity of the fauna and silt/clay content. Stations SB2 and SB3 which had silt/clay content of from 51 to 74.3 percent had the lowest numbers of species (average of 48 and 55 per replicate) while those with lower silt/clay content were generally higher. Station SB1 averaged 73 species per replicate, SB7, 67 per replicate and MH, 73 species per replicate.

Small polychaetes were the dominant taxa at all sites. The ten most numerous species comprised from 77 to 99 percent of the total individuals at the Stellwagen stations and from 70 to 76 percent of the total at Mud Hole. *Spio limicola* was the numerical dominant at six of the seven sites in the Stellwagen survey area. This species accounted for from 24 to 41% of the total individuals. Two additional polychaetes, *Prionospio steenstrupi* and *Anobothrus gracilis* were the next most dominant species comprising 5 to 24 percent of the total. *Anobothrus gracilis* was the dominant species at one site (SB1; 22.5 percent) with *Maldane sarsi* and *Prionospio* the next most common species. The only non-polychaete species listed among the dominants were three bivalves, *Nucula delphinodonta*, *Thyasira gouldii* and *Crenella decussata*. These comprised from 2 to 4 percent of the total individuals in the 3 grab samples.

At the Mud harbor sites *Spio limicola* was dominant at MH2B and *Prionospio* was more abundant at MH4B. The isopod *Edotea montosa* was the only crustacean to appear the dominant species list at any site (MH2B). The remaining dominant species in samples from Mud Hole included many species that were dominant along the Stellwagen transect. There was considerable overlap in the dominant species for the seven Stellwagen sites. Apart from the three very dominant species, *Spio limicola*, *Prionospio steenstrupi* and *Anobothrus gracilis*, several additional poychaetes were common to the dominant species lists. These included *Levinsenia gracilis*, *Aricidea quadrilobata* and *Ninoe nigripes*.

Although these areas are subjected to disturbances during major storms there is considerable persistence to the benthic infauna at these depths in Cape Cod Bay and Massachusetts Bay. Benthic infaunal samples collected during the trawl effects evaluation study at MH2B and MH4B in 2002 (Table 4.6.2) are very similar to those reported from the same sites two years later. *Spio limicola* and *Prionospio* were the dominant species in the pre-trawl and post-trawl samples at both of these sites. Other species which were among the dominant species in both sampling events, were *Tharyx acutus, Mediomastus californiensis, Nucula delphinodonta, Thyasira gouldii,* and

Anobothrus gracilis. Faunal diversity and densities were also very similar in spite of the two–year time difference. Long-term studies such as the Massachusetts Water Resources Authority (MWRA) monitoring program and the Gloucester 301(h) monitoring program have documented the persistence of these benthic assemblages over periods of up to 15 years (Maciolek at al., 2004; Michael and Hall, 2004). The dominant species for samples taken in similar sediments as those found in the Stellwagen transect area the same.

Table 4.6.1 Dominant Benthic Species at Stellwagen – Long Bank transect

SB 1

No. of species **105**
No. of individuals **2498**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Anobothrus gracilis*	564	22.58	22.58
2	*Maldane sarsi*	293	11.73	34.31
3	*Prionospio steenstrupi*	272	10.89	45.20
4	*Spio limicola*	229	9.17	54.36
5	*Levinsenia gracillis*	186	7.45	61.81
6	*Euclymeninae sp. A*	113	4.52	66.33
7	*Aricidea quadrilobata*	86	3.44	69.78
8	*Thyasira gouldii*	76	3.04	72.82
9	*Exogone verugera*	63	2.52	75.34
10	*Ninoe nigripes*	50	2.00	77.34

SB 2

No. of species **76**
No. of individuals **1822**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	436	23.93	23.93
2	*Levinsenia gracillis*	251	13.78	37.71
3	*Prionospio steenstrupi*	191	10.48	48.19
4	*Anobothrus gracilis*	163	8.95	57.14
5	*Aricidea quadrilobata*	145	7.96	65.09
6	*Ninoe nigripes*	107	5.87	70.97
7	*Chaetozone setosa*	57	3.13	74.09
8	*Maldane sarsi*	51	2.80	76.89
9	*Mediomastus californiensis*	41	2.25	79.14
10	*Cossura longocirrata*	39	2.14	81.28

SB 3

No. of species **87**
No. of individuals **2350**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	731	31.11	31.11
2	*Anobothrus gracilis*	229	9.74	40.85
3	*Prionospio steenstrupi*	146	6.21	47.06
4	*Chaetozone setosa*	113	4.81	51.87
5	*Levinsenia gracillis*	108	4.60	56.47
6	*Ninoe nigripes*	107	4.55	61.02
7	*Euclymeninae sp. A*	91	3.87	64.89
8	*Aphelochaeta marioni*	90	3.83	68.72
9	*Aricidea quadrilobata*	88	3.74	72.47
10	*Exogone verugera*	61	2.60	75.06

SB 4

No. of species **89**
No. of individuals **2841**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	1073	37.77	37.77
2	*Prionospio steenstrupi*	389	13.69	51.46
3	*Anobothrus gracilis*	139	4.89	56.35
4	*Aricidea quadrilobata*	110	3.87	60.23
5	*Galathowenia oculata*	101	3.56	63.78
6	*Chaetozone setosa*	95	3.34	67.12
7	*Ninoe nigripes*	84	2.96	70.08
8	*Thyasira gouldii*	74	2.60	72.69
9	*Levinsenia gracilis*	57	2.01	74.69
10	*Euclymeninae sp. A*	54	1.90	76.59

SB 5

No. of species **97**
No. of individuals **3562**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	1158	40.76	40.76
2	*Anobothrus gracilis*	683	24.04	64.80
3	*Prionospio steenstrupi*	313	11.02	75.82
4	*Galathowenia oculata*	143	5.03	80.85
5	*Thyasira gouldii*	105	3.70	84.55
6	*Aricidea quadrilobata*	100	3.52	88.07
7	*Ninoe nigripes*	85	2.99	91.06
8	*Maldane sarsi*	78	2.75	93.80
9	*Crenella decussata*	77	2.71	96.52
10	*Nucula delphinodonta*	74	2.60	99.12

SB 6

No. of species **97**
No. of individuals **3052**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	784	27.60	27.60
2	*Anobothrus gracilis*	629	22.14	49.74
3	*Prionospio steenstrupi*	446	15.70	65.43
4	*Levinsenia gracillis*	138	4.86	70.29
5	*Maldane sarsi*	102	3.59	73.88
6	*Nucula delphinodonta*	101	3.56	77.44
7	*Thyasira gouldii*	81	2.85	80.29
8	*Mediomastus californiensis*	66	2.32	82.61
9	*Galathowenia oculata*	55	1.94	84.55
10	*Crenella decussata*	54	1.90	86.45

SB 7

No. of species **104**
No. of individuals **2750**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	902	31.75	31.75
2	*Prionospio steenstrupi*	588	20.70	52.45
3	*Anobothrus gracilis*	167	5.88	58.32
4	*Levinsenia gracillis*	122	4.29	62.62
5	*Thyasira gouldii*	114	4.01	66.63
6	*Ninoe nigripes*	86	3.03	69.66
7	*Nucula delphinodonta*	59	2.08	71.74
8	*Aphelochaeta marioni*	55	1.94	73.67
9	*Mediomastus californiensis*	49	1.72	75.40
10	*Nereis grayi*	44	1.55	76.94

Table 4.6.2 Dominant Benthic Species at Mud Hole

MH 2B

No. of species **99**
No. of individuals **2761**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	626	22.67	22.67
2	*Prionospio steenstrupi*	578	20.93	43.61
3	*Nucula delphinodonta*	195	7.06	50.67
4	*Tharyx acutus*	112	4.06	54.73
5	*Edotea montosa*	99	3.59	58.31
6	*Ninoe nigripes*	93	3.37	61.68
7	*Mediomastus californiensis*	73	2.64	64.32
8	*Aphelochaeta marioni*	65	2.35	66.68
9	*Thyasira gouldii*	52	1.88	68.56
10	*Eteone longa*	42	1.52	70.08

MH 4B

No. of species **94**
No. of individuals **2600**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Prionospio steenstrupi*	677	26.04	26.04
2	*Spio limicola*	581	22.35	48.38
3	*Ninoe nigripes*	140	5.38	53.77
4	*Levinsenia gracillis*	125	4.81	58.58
5	*Tharyx acutus*	104	4.00	62.58
6	*Mediomastus californiensis*	104	4.00	66.58
7	*Thyasira gouldii*	86	3.31	69.88
8	*Aricidea quadrilobata*	48	1.85	71.73
9	*Eteone longa*	43	1.65	73.38
10	*Leitoscoloplos acutus*	39	1.50	74.88
11	*Aricidea catherinae*	39	1.50	76.38

Station MH02-2B

No. of species **107** **Avg. Sp. Per grab** **69**
No. of individuals **3589** **Avg Indiv. Per grab** **1196**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	1083	30.18	30.18
2	*Prionospio steenstrupi*	679	18.92	49.09
3	*Dipolydora socialis*	209	5.82	54.92
4	*Nucula delphinodonta*	207	5.77	60.69
5	*Mediomastus californiensis*	140	3.9	64.59
6	*Tharyx acutus*	129	3.59	68.18
7	*Thyasira gouldii*	103	2.87	71.05
8	*Maldane sarsi*	93	2.59	73.64
9	*Anobothrus gracilis*	63	1.76	75.4
10	*Apistobranchus typicus*	60	1.67	77.07

Station MH02-2B - P1

No. of species	**98**		**Avg. Sp. Per grab**	**64**
No. of individuals	**2596**		**Avg Indiv. Per grab**	**865**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	863	33.24	33.24
2	*Prionospio steenstrupi*	433	16.68	49.92
3	*Dipolydora socialis*	120	4.62	54.55
4	*Tharyx acutus*	98	3.78	58.32
5	*Mediomastus californiensis*	84	3.24	61.56
6	*Maldane sarsi*	78	3	64.56
7	*Anobothrus gracilis*	71	2.73	67.3
8	*Thyasira gouldii*	66	2.54	69.84
9	*Nucula delphinodonta*	60	2.31	72.15
10	*Aphelochaeta marioni*	51	1.96	74.11

Station MH02-4B

No. of species	**83**		**Avg. Sp. Per grab**	**57**
No. of individuals	**2671**		**Avg Indiv. Per grab**	**890**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Spio limicola*	909	34.03	34.03
2	*Prionospio steenstrupi*	371	13.89	47.92
3	*Dipolydora socialis*	179	6.7	54.62
4	*Tharyx acutus*	137	5.13	59.75
5	*Thyasira gouldii*	114	4.27	64.02
6	*Mediomastus californiensis*	98	3.67	67.69
7	*Anobothrus gracilis*	88	3.29	70.98
8	*Aphelochaeta marioni*	80	3	73.98
9	*Maldane sarsi*	80	3	76.97
10	*Levinsenia gracillis*	70	2.62	79.6

Station MH02-4B - P1

No. of species	**81**		**Avg. Sp. Per grab**	**56**
No. of individuals	**2651**		**Avg Indiv. Per grab**	**884**

Rank	Species Name	Count	% of Total	Cummulative %
1	*Prionospio steenstrupi*	685	25.84	25.84
2	*Spio limicola*	654	24.67	50.51
3	*Tharyx acutus*	152	5.73	56.24
4	*Mediomastus californiensis*	105	3.96	60.2
5	*Anobothrus gracilis*	102	3.85	64.05
6	*Levinsenia gracillis*	93	3.51	67.56
7	*Aphelochaeta marioni*	68	2.57	70.12
8	*Dipolydora socialis*	66	2.49	72.61
9	*Thyasira gouldii*	58	2.19	74.8
10	*Aricidea catherinae*	55	2.07	76.88

Faunal data was subjected to ordination and cluster analysis in order to evaluate the relationships between sites. In both cases, raw data from the three replicate samples was combined and subjected to a square root transformation to reduce the influence of abundant species. Ordination methods included correspondence analysis and principal components analysis. In the cluster analysis, the similarity coefficient used was the Bray and Curtis measure and clustering was in the normal or "Q" mode using group average sorting (UPGMA).

In the ordination analyses (Figures 4.6.1 and 4.6.2), Station 7 on the Stellwagen site was clearly separated from other samples from that area. Samples from Mud Hole were also separated along one axis with MH2B being the most distinct. The classification or cluster analysis (Figure 4.6.3), confirmed these results with the two Mud Hole separated from all of the Stellwagen samples. Stations SB1 and SB2 and SB7 were the most distinctive of sites within that group. Examination of the faunal data shows that the separation of MH2B from other sites was due to lower numbers of the polychaete *Anobothrus gracilis* and higher numbers of both *Tharyx acutus* and *Aricidea catherinae*, two polychaetes which were present in low numbers or absent at other sites. There were also high numbers of the isopod *Edotea montosa* and the bivalves *Artica islandica* and *Nucula delphinodonta*. The sand dollar *Echinarachnius parma* was found at both MH2B and MH4B while only a single specimen of this species was found at one Stellwagen site (SB5-1). Stations SB1 and SB2 had higher numbers of *Levinsenia gracilis* than other site and SB1 had very high densities of *Maldane sarsi* (mean per grab = 97), a species which was found in lower numbers, but present at all other sites. Separation of SB7 from other stations in the community analyses based on faunal data was more subtle, but appears to due to higher numbers of the polychaetes *Nereis grayi* and *Scalibregma inflatum* and higher numbers of an amphipod, *Harpinia propinqua.*

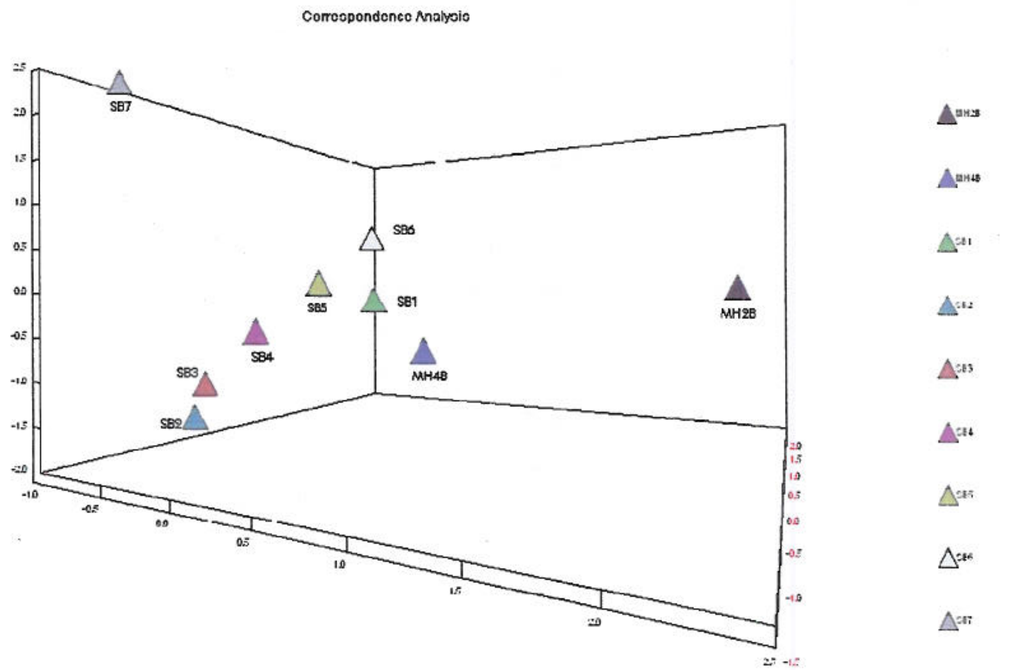


Figure 4.6.1. Correspondence analysis, Long Bank benthic data

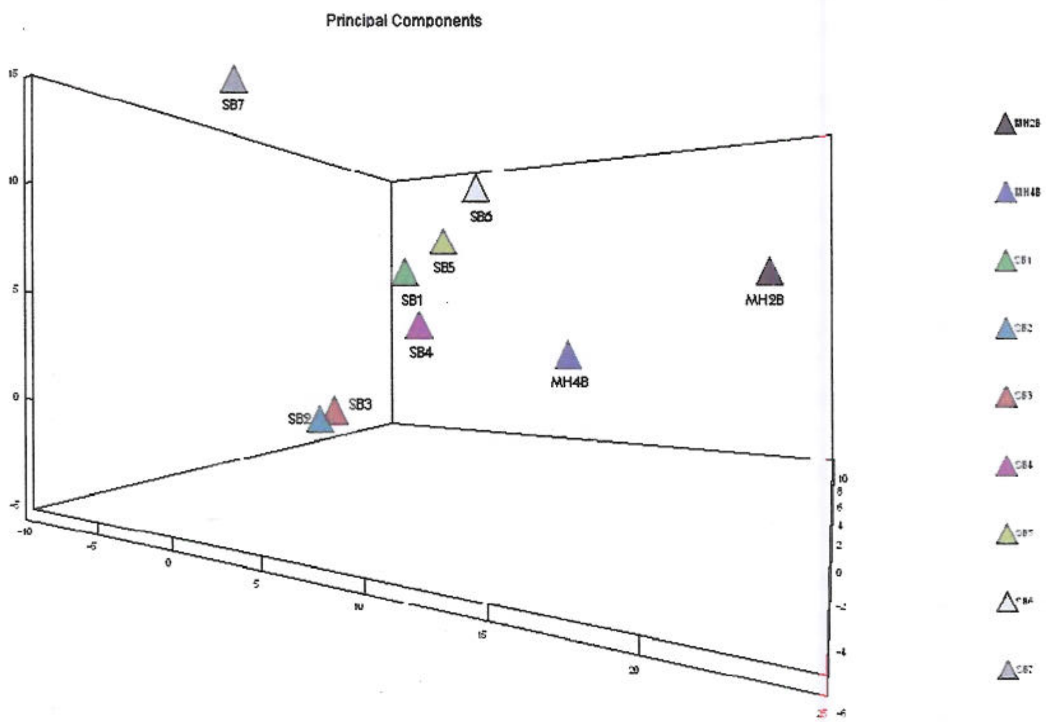


Figure 4.6.2. Principal components analysis of Long Bank benthic data

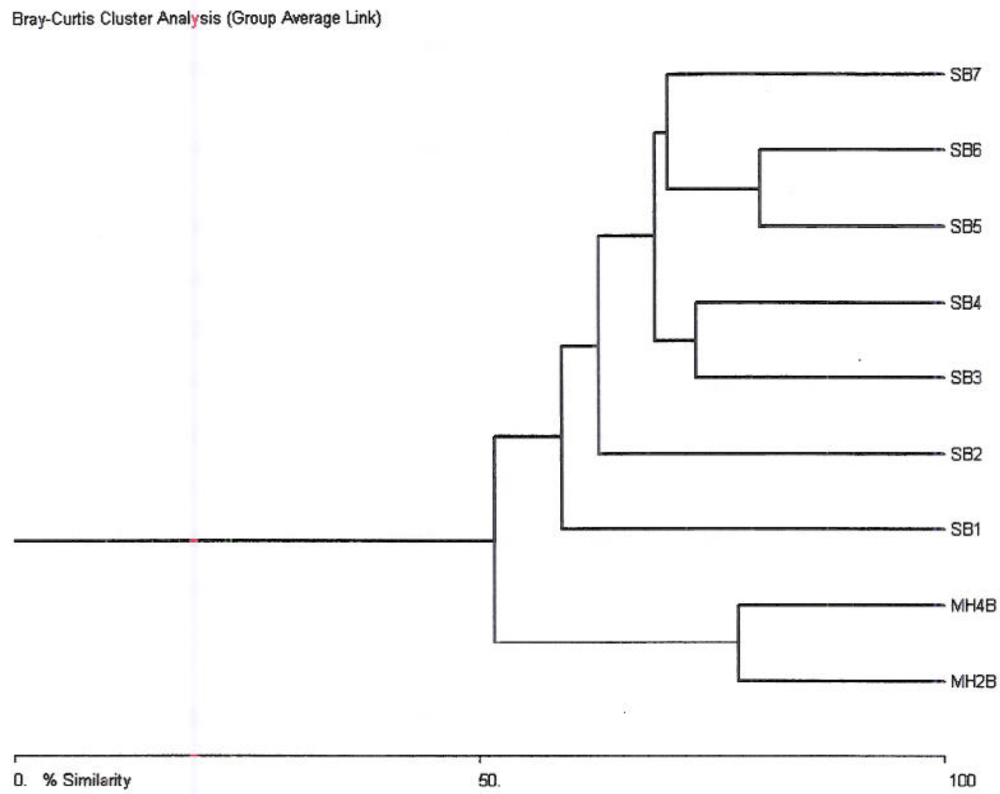


Figure 4.6.3. Cluster analysis, Long Bank benthic data

4.6.3 SEDIMENTS

Results for particle size analysis are listed in Table 4.6. The silt/clay content of sediments along the transect ranged from 19 to 20 percent at Station 7, to from 71 to 74 percent at Station 2. Median particle size ranged form 2.65 phi in one replicate at Station 7 to 5.2 phi in the second replicate from Station 2. The sediments were not well sorted with a quartile deviation range of from 0.9 to 1.37 phi. Stations 3, 4, 5 and 6 had significant amounts of very fine sand (0.062 – 0.125 mm). Sand (0.25 – 0.5 mm) was an important component at Stations 5, 6 and 7.

The two sites at Mud Hole had lower silt/clay content with a higher median grain size. At MH2B silt/clay content was 16.6 percent in one replicate and 9.7 percent in the second. St MH4B silt/clay content was 17.9 to 18.9 percent. Fine sand was the modal grain size at MH2B and sand was the dominant particle size at MH4B. Both sites had significant amounts of fine and very fine sand.

In these types of sediment silt/clay content is the primary determinant of species composition and the lower silt/clay content at Stations SB7, MH2B and MH4B explains their separation from other sites in the community analyses

TABLE 4.6.3
Sediment Particle Size
STELLWAGEN / LONG BANK AND MUD HOLE BENTHIC STATIONS

	SB1-1	SB1-2	SB2-1	SB2-2	SB3-1	SB3-2	SB4-1	SB4-2	SB5-1	SB5-2
> 2 mm	0.77	0.67	0.58	0.64	0.32	0.19	0.4	0.08	0.24	1
1-2 mm	0.65	1.05	1.13	1.27	1.2	0.76	0.99	0.11	0.65	0.79
0.5-1 mm	2	2.5	2	2.77	0.61	1.72	0.9	0.38	9.15	7.11
0.25-0.5 mm	15.84	14.81	3.74	4.12	1.62	3.66	12.44	10.67	28.75	25.33
0.125-0.250 mm	36.6	30.57	9.19	7	1.83	4.95	20.18	19.13	7.16	6.47
0.062-0.125 mm	12.38	12.71	12.4	9.66	40.9	37.53	33.5	34.26	27.97	29.85
< 0.062 mm	31.75	37.69	70.95	74.53	54.51	51.19	31.58	35.36	26.06	29.44
median (phi)	2.9	3.1	5.1	5.23	4.3	4.12	3.45	3.58	3.18	3.3
quartile dev (phi)	1.14	1.35	1.32	1.24	1.05	1.09	1	1.02	1.29	1.37

	SB6-1	SB6-2	SB7-1	SB7-2	MH2B-1	MH2B-2	MH4B-1	MH4B-2
> 2 mm	0.8	1.59	1.93	0.58	0	0.6	0.75	0.71
1-2 mm	0.94	1.84	0.44	0.41	0.22	0.2	0.55	0.42
0.5-1 mm	6.72	6.4	3.83	4.76	0.58	0.22	4.7	5.18
0.25-0.5 mm	26.18	25.65	28.96	31.51	1.52	1.74	30.53	32.54
0.125-0.250 mm	9.47	9.09	18.02	17.72	42.34	56.81	21.32	18.44
0.062-0.125 mm	30.77	31.1	26.72	25.98	38.74	30.74	23.24	24.82
< 0.062 mm	25.12	25.32	20.09	19.02	16.59	9.68	18.9	17.89
median (phi)	3.18	3.18	2.65	2.85	3.13	2.9	2.74	2.6
quartile dev (phi)	1.13	1.18	1.02	0.9	0.55	0.42	1.08	0.98

5 DISCUSSION

Significant logistical problems were encountered during this study. These included the timetable, weather issues, accessibility at sites due to fixed gear, and performance of some equipment. Most of the work was completed (as per the budget) on smaller vessels of less than 50 ft length, which could only operate in favorable weather conditions at sites up to 25 miles from Gloucester (Pigeon Hills). The schedule, planned in the proposal, was based in the assumption that GeoSwath and sidescan sonar work would be completed in the fall of 2003 allowing the entire summer of 2004 for follow-up habitat evaluation. The contract signature date of September 28 combined with a rather windy period in October and November meant that the initial components of the project were not completed within the proposed time period. The fall and winter were used to interview fishermen and evaluate prospective sites. The GeoSwath instrument had to be rented and was not available until late July early August 2004. There were a limited number of survey days available in the budget and it seemed appropriate to get some results from the sidescan and GeoSwath surveys before targeting specific area for video work. Contract expiry date was September 30th 2004, leaving little time for biological survey work and so a contract extension was requested and obtained (for the maximum allowable time) for an additional six months to March 30, 2004. While this was a satisfactory length of time to complete the work there were significant problems getting this done due to fall, winter, and spring weather conditions. In retrospect, the project would have benefited by encompassing two summer periods to avoid weather difficulties.

Because the sites chosen were prime fishing spots, the presence of fixed gear hindered, and sometime prevented deployment of research equipment in certain areas. On one occasion a large gill net was set on the northeast side of East Pigeon Hill, clearly well inside the permanent closure area. It was not clear whether this was set for research or commercial purposes. Due to the threat of entanglement, the presence of assorted commercial set gear dictated where video drifts, profiles and camera deployments could be undertaken. These difficulties did however highlight one advantage of GeoSwath over sidescan since the swath transducer is positioned just below the surface, allowing for some element of flexability compared to the sidescan which involves a towed wire.

Several of the survey methods did not perform up to expectations. The baited video system was vulnerable to currents and in some cases the camera did not set at an appropriate angle after reaching the sea floor. This, and the seasonality of fish populations, resulted in many tapes with nothing on them. There were also significant issues with lighting. Further testing needs to be done with light sources and alternate camera systems. The original design as used by Willis et al., which we copied, worked well in depths of less than 30 meters with a good supply of natural light. Results in offshore deeper areas were not good enough with the gear we used to recommend this approach for assessment purposes. Researchers at the Australian Institute of Marine Science (Cappo et al, 2004) used a modified approach to underwater video assessment at the Great Barrier Reef. Cheap Hi8 "Handicams" were installed in underwater housings made of PVC sewer pipe. These systems were baited with 1 kg of pilchards and set in strings of six – each with a rope for hauling and a string of surface buoys. The cameras recorded for 1.5 to 3 hours and the timing and abundance of fish visits were documented using the time code stamped on the tape. The gear setup was called baited remote underwater videos, or BRUVS and offers an alternative to the system we used. One main advantage of that system is the lack of an electrical umbilical cord to the surface, which was a problem at times of high current speeds with our gear. These BRUVS were tested at depths up to 100 meters in Australia but in an area that has much better visibility than we encountered in the Gulf of Maine.

In that study, trawls were made close and parallel to a long-shore set of five BRUVS set at regular intervals along one nautical mile. For each species, the sum of the maximum number of fish sighted on BRUVS at any one time was compared with the number of fish caught. The two techniques recorded different components of the fauna on fish grounds although there was a considerable overlap of species common to both techniques. Both techniques indicated very similar patterns of grouping of fish species assemblages, despite sampling different components of the fauna. The trawls caught mainly small sedentary demersal species such as flatfishes while the BRUVS recorded more larger mobile species from a much wider size range of families including sharks and rays, trevallies and mackerel. The BRUVS technique more precisely and accurately described and predicted the fish assemblages in the field comparison.

The issues of currents and light are the two major factors that need to be addressed. BRUVS could probably be used in areas of the Gulf of Maine where significant tidal currents exist but further testing needs to be done with respect to light sources. One advantage of the BUV system as used by Willis et al is that fish can be measured more easily. The camera is focused down on the sea floor at a known height above the surface. Cameras in the BRUVS system were directed horizontally and, without knowing the distance between the fish and the lens, it is more difficult to get a reliable estimate of length. The system will however give equally good estimates of relative numbers and diversity.

The mini ROV, due to its size and weight, was also very vulnerable to currents, and with a cable length of just 100 meters, the area that could be covered at a site was very limited. The cameras in the ROV were not as sophisticated as those on the video sled which was the most effective survey tool.

In spite of the relatively small number of fishermen interviewed there was a good consensus for the selection of the northern site at Pigeon Hills, an area that used to be worked by all types of fishermen. Trawling was conducted to the western side of Pigeon Hills and between Pigeon Hills and what is now known as Sanctuary Hill. Historically, it has also been a very active site for longlining, gill nets, and recreational charter boats. For some fishermen the area was also a favorite site for large pelagics such as tuna. Selection of a southern site was more complicated. There are a variety of areas on Stellwagen Bank and Tillies Bank that are productive for a variety of fishing methods. Seasonality is a factor in the abundance of fish populations in specific areas and many fishermen have their own particular favorite sites based on personal success. It was much more difficult to get a consensus for a study area in the southern area which was limited in size and other factors such as distance from shore and depth. Whether the input from a larger number of fishermen would have produced more of a consensus is questionable. The choice of a site further offshore would have dramatically increased the cost of the project.

We were unable to identify specific factors that result in these areas being considered essential fish habitat other than the fact that they are areas of highly variable habitat and complex hydrography. They are known to be productive regions in terms of commercial fisheries and one likely reason is the diversity of the physical environment. Ecotones, which are the intersection of two or more habitat types, are especially important for mobile species since they can exploit resources in more than one habitat over a short distance. This often results in an "edge" effect along the boundary line where diversity appears to be higher than normal. In the case of Pigeon Hills and the rock outcrops at either end of the Stellwagen/Long Bank transect, fish can exploit a different bottom type (sandy mud, cobble, boulders, ledge), depth, and (in summer) temperature regimes over short distances. This can only enhance the variety of food sources available and provide the appropriate refuge for different stages of the life cycle.

Primary productivity in the waters associated with banks and shallow rock outcrop areas is another probable factor in fisheries productivity. The influence of internal waves on chlorophyll distribution in the central Gulf of Maine was reported by Witman et al (1993). Hydrographic measurements indicated that the thermocline and the phtyplankton-rich chlorophyll maximum layer were vertically displaced over a rocky pinnacle (Ammen Rock at Cashes Ledge) by internal waves with maximum amplitudes of 27 m. These predictable downwelling events were linked to 2- to 3-fold in creases in chlorophyll *a*, an indicator of phytoplankton concentration, in pulses of warm water recorded 4 cm above the bottom at 29-m depth. The 1.5-5.6°C temperature fluctuations had an average period of 10.6 minutes and were generated on both ebb and flood tides. Local lee waves and the arrival of solitons propagated from Georges Bank were hypothesized to explain the timing of the internal waves

Stellwagen Bank serves as a boundary between the Gulf of Maine to the east and Massachusetts Bay to the west. Oceanographic features on the bank are related to the strong tidal currents driven by a 3-meter tidal range. During the spring and summer, when there is a significant density difference between the surface and bottom layers, large amplitude internal waves are generated by the tidal flow across the shallow bank. The shallow depths of Stellwagen and Long Bank combined with waves and currents provide mixing for maintaining nutrient supply to the upper layers at or near the banks. The flows associated with the waves propagated over shallow areas increase shear in the pycnocline, leading to enhanced vertical diffusion.

An important aspect of this project was the involvement of local fishermen and their vessels in the survey efforts. To that end, selection of the survey gear considered ease of installation on vessels of opportunity. The GeoSwath system is better suited for this type of installation than many other conventional beam-forming multibeam bathymetric systems. Transfer of the system from the F/V Christopher Andrew to the F/V Lady Jane was greatly facilitated by the fishermen's intimate knowledge of their on-board rigging and winch systems, and was accomplished within 2-hours.

The GeoAcoustics Inc. GeoSwath 125-kHz interferometric bathymetric system provided fine-scale seabed bathymetric data and coarse-scale side scan sonar (backscatter) data. Bathymetric data collected with this system allowed characterization of seabed features as small as approximately 2 m in water depths approaching 100 m. When merged with the swath side scan sonar data, the GeoSwath provided acceptable discrimination between major benthic substrates. An advantage of the swath side-scan sonar data relative to conventional side scan sonar data was the ability to perform true slant-range corrections which incorporated seabed topography. Thus, the geographic placement of depicted features on the swath mosaic is more accurate than on the traditional side scan sonar mosaic, particularly in areas of high relief.

The resolution of the swath system was limited by along-track data density, determined by the hydrographer's selected range and subsequent ping rate. Signal refraction caused by the strongly stratified water column limited the effective swath width to approximately 180- to 200-m for the highest quality bathymetric data. It is likely that substantially wider swaths could be acquired during isothermal or weakly stratified periods. Resolution also appears to have been slightly impaired by very short period vibrations in the over-the-side mounting arrangement used to deploy the GeoSwath transducer array as large masses of floating rockweed became entangled in the transducer boom. These movements appear as low-magnitude across-track artifacts in the swath bathymetric data. We note that this impairment would likely be eliminated by a through-hull mounting system. Limitations associated with GeoSwath software have likely been addressed by the recent GeoAcoustics release of the GeoSwath Plus software suite.

The Edgetech, Inc. TD272 towed side scan sonar system provided detailed imagery of the seafloor with resolution of approximately 10- to 20 cm. This system was also affected by thermocline-induced refraction, but the ability to manipulate towfish height helped to minimize degradation of data quality. The side scan sonar data was collected using a 100-kHz signal and swath widths of 160- to 300-m. Data manipulation and visualization capabilities afforded by relatively low cost Chesapeake Technology, Inc. software enhanced side scan sonar usability. Although the locations of features identified by the side scan sonar system would theoretically be less accurate than those identified by the swath system due to the "flat bottom" assumption required for side scan sonar slant-range corrections, the degree of imprecision is judged to be minimal relative to the scale of the survey area and the high discriminatory capability of the towed system.

The SyQwest, Inc. Stratabox sub-bottom profiling system was easily deployed on a fishing vessel using the same side-mounted system shown on Figure 3.3b. The onboard hardware required to operate this 12-volt system was limited to the small lightweight amplifier/signal processor and a laptop computer running proprietary acquisition software. The few transects surveyed with this system allowed preliminary characterization of the depositional characteristics and glacial history of each survey site.

As reported by the local fishermen, the fish catches at these sites can be highly seasonal and affected by water temperature and the presence of certain prey items. Few fish were observed using video during the study with the exception of some large schools of pollock in the spring at Pigeon Hills. To accurately use underwater video surveys to estimate fish populations and bottom habitat relationships a series of monthly underwater video surveys over the same transects should be performed.

Other factors that can affect the results of the underwater video surveys include water visibility, water currents and sea state that vary the speed of the video sled and the height off the bottom, and the behavior of different species. For example, some species such as cod fish are extremely timid and usually stay out of the focal range of the video camera while other species, such as flounder and red hake are not bothered by the sound of sled scraping the bottom and the bright video lights and stay in the field of view until the last moment. These factors complicate the analysis of the underwater video data and potentially bias the data for use in fish habitat assessments.

The data generated by these surveys allow detailed inspection of habitat characteristics within each of the survey sites. The Pigeon Hill site has been the focus of several ecological and fisheries investigations (e.g., Hulbert et al., 1982, *Ecosystem definition and community structure of the macrobenthos of the NEMP monitoring station at Pigeon Hill in the Gulf of Maine: NOAA Technical Memorandum NMFS-F/NEC-14*). It is our hope that the data generated by these surveys will aid additional biological investigations of this site.

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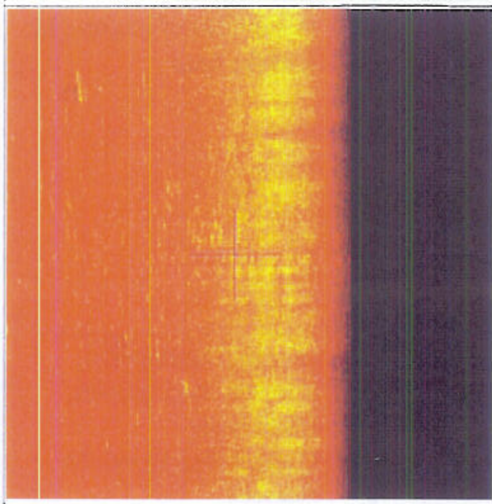
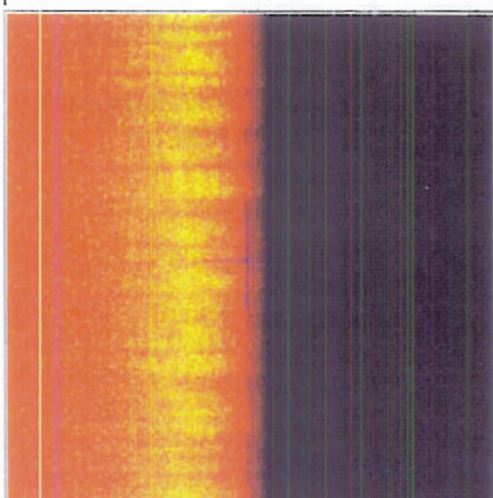
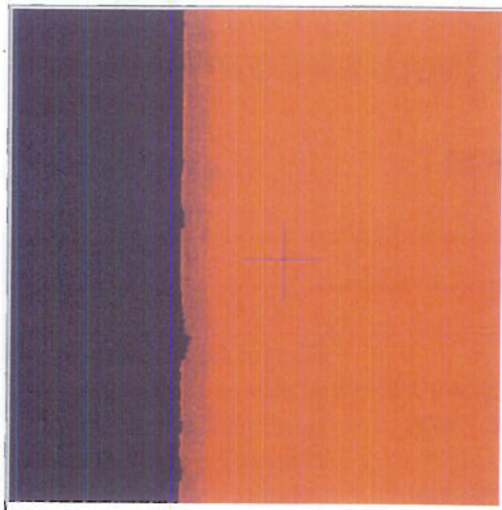
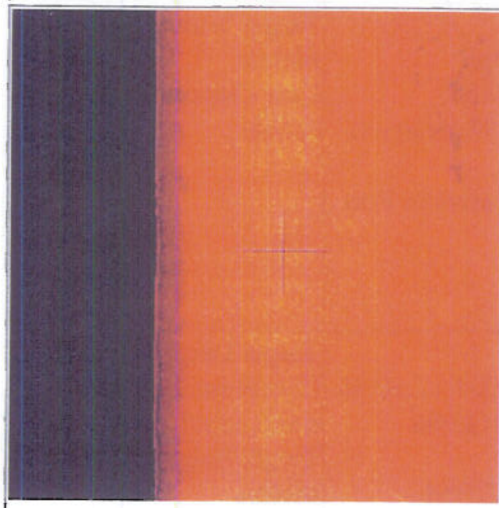
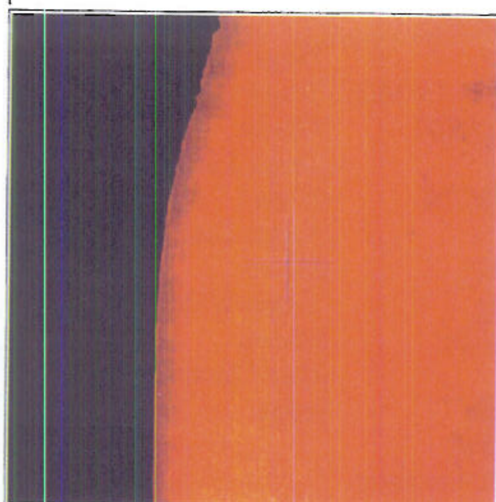
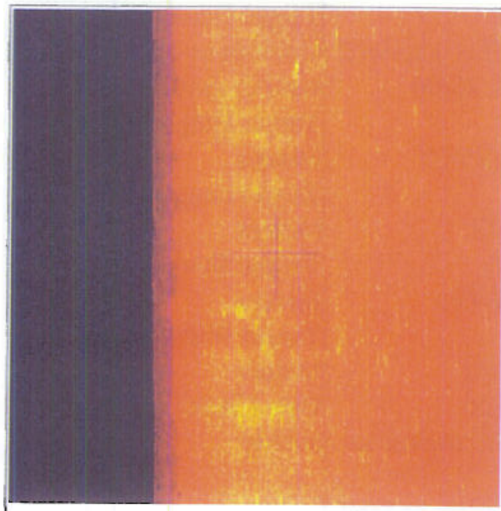
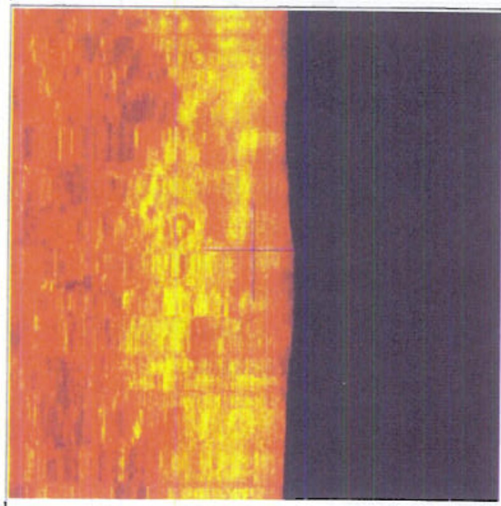
APPENDIX A

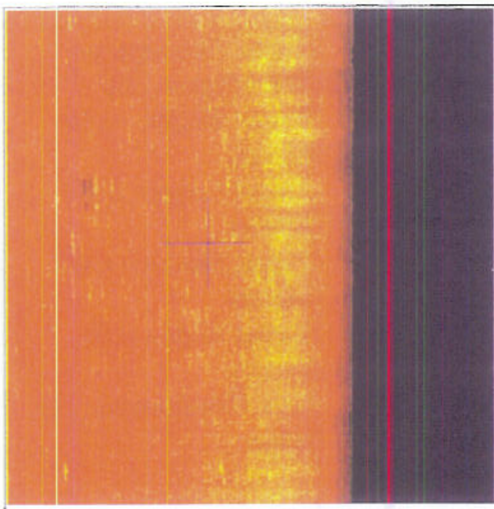
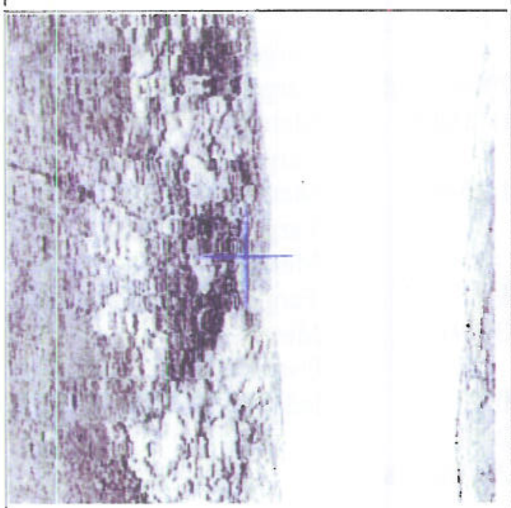
REPRESENTATIVE SIDE SCAN SONAR IMAGERY FROM PIGEON HILL 100 KHZ TOWED SYSTEM

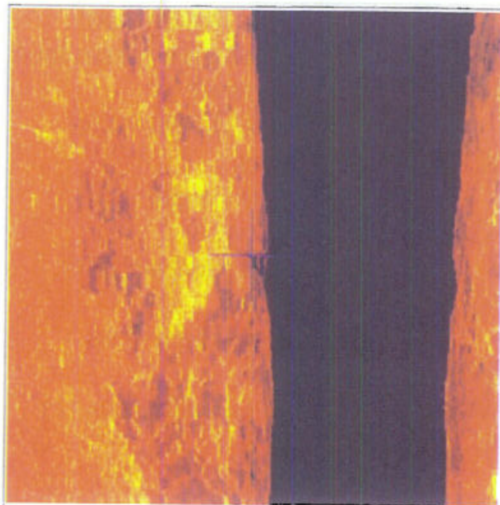
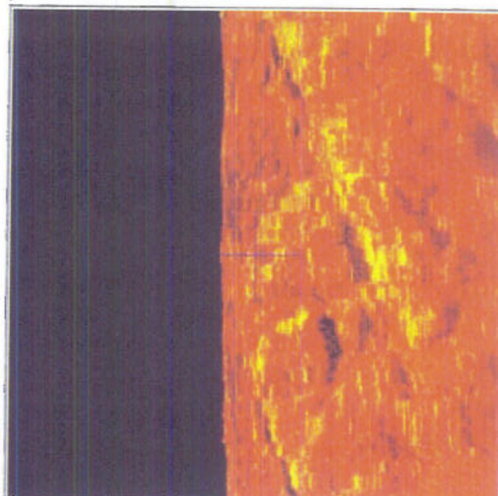
Target Elements		
Target Image	**Target Info**	**User Entered Info**
	**Target: Contact0001** Sonar Time at Target: 10/07/2004 17:15:56 Target Capture Time Local: 01/25/06 09:46:44 Target Capture Time UTC: 01/25/06 14:46:44 Target Click Position (GEO): 42° 46.71476' N 070° 15.77645' W Target Click Position (UTM83-19): N:4737000.26 E:396690.25 Acoustic Source File: H:\EFH\ph sss\raw\line1-150m.xtf, Ping:2652 Horizontal range to target: 89.10 meters to Port side Slant range to target: 102.23 meters to Port side Event Number: 0 Line Name: line1-150m	Target Description: Cobbles over coarse sand and gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): cobble
	**Target: Contact0002** Sonar Time at Target: 10/07/2004 17:10:48 Target Capture Time Local: 01/25/06 09:46:05 Target Capture Time UTC: 01/25/06 14:46:05 Target Click Position (GEO): 42° 46.23170' N 070° 15.75618' W Target Click Position (UTM83-19): N:4736105.81 E:396704.50 Acoustic Source File: H:\EFH\ph sss\raw\line1-150m.xtf, Ping:1285 Horizontal range to target: 56.10 meters to Port side Slant range to target: 76.78 meters to Port side Event Number: 0	Target Description: Coarse sand, gravel, small cobbles Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): gravel

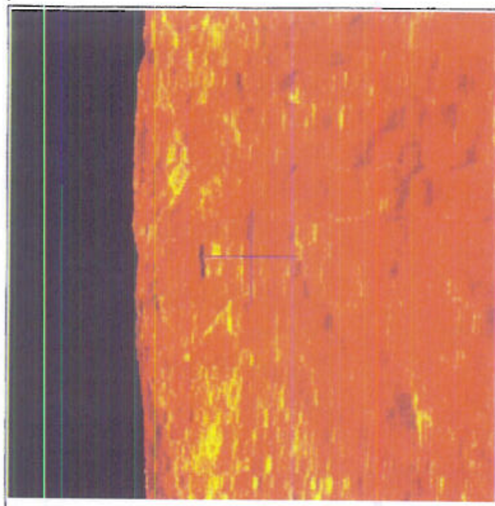
	Line Name: line1-150m	
	**Target: Contact0003** Sonar Time at Target: 10/07/2004 13:30:27 Target Capture Time Local: 01/25/06 09:49:32 Target Capture Time UTC: 01/25/06 14:49:32 Target Click Position (GEO): 42° 45.57897' N 070° 15.43505' W Target Click Position (UTM83-19): N:4734891.23 E:397124.36 Acoustic Source File: H:\EFH\ph sss\raw\line3-150m.xtf, Ping:227 Horizontal range to target: 94.29 meters to Stbd side Slant range to target: 111.06 meters to Stbd side Event Number: 0 Line Name: line3-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand
	**Target: Contact0004** Sonar Time at Target: 10/07/2004 15:09:57 Target Capture Time Local: 01/25/06 09:47:43 Target Capture Time UTC: 01/25/06 14:47:43 Target Click Position (GEO): 42° 46.03482' N 070° 15.43191' W Target Click Position (UTM83-19): N:4735734.83 E:397141.22 Acoustic Source File: H:\EFH\ph sss\raw\line3r-150.xtf, Ping:201 Horizontal range to target: 94.52 meters to Stbd side Slant range to target: 107.61 meters to Stbd side Event Number: 0 Line Name: line3r-150	Target Description: Coarse sand, gravel, shell hash Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand

	**Target: Contact0005** Sonar Time at Target: 10/07/2004 15:19:02 Target Capture Time Local: 01/25/06 09:48:13 Target Capture Time UTC: 01/25/06 14:48:13 Target Click Position (GEO): 42° 46.83549' N 070° 15.41798' W Target Click Position (UTM83-19): N:4737216.41 E:397182.29 Acoustic Source File: H:\EFH\ph sss\raw\line3r-150.xtf, Ping:2620 Horizontal range to target: 93.89 meters to Stbd side Slant range to target: 107.06 meters to Stbd side Event Number: 0 Line Name: line3r-150	Target Description: Cobbles over coarse sand & gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): cobble
	**Target: Contact0006** Sonar Time at Target: 10/07/2004 15:33:51 Target Capture Time Local: 01/25/06 09:50:52 Target Capture Time UTC: 01/25/06 14:50:52 Target Click Position (GEO): 42° 45.94832' N 070° 15.31848' W Target Click Position (UTM83-19): N:4735572.43 E:397293.52 Acoustic Source File: H:\EFH\ph sss\raw\line4-150m.xtf, Ping:256 Horizontal range to target: 97.20 meters to Stbd side Slant range to target: 111.07 meters to Stbd side Event Number: 0 Line Name: line4-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand

	**Target: Contact0007** Sonar Time at Target: 10/07/2004 15:43:16 Target Capture Time Local: 01/25/06 09:50:38 Target Capture Time UTC: 01/25/06 14:50:38 Target Click Position (GEO): 42° 46.78476' N 070° 15.31395' W Target Click Position (UTM83-19): N:4737120.39 E:397322.73 Acoustic Source File: H:\EFH\ph sss\raw\line4-150m.xtf, Ping:2766 Horizontal range to target: 91.44 meters to Stbd side Slant range to target: 104.76 meters to Stbd side Event Number: 0 Line Name: line4-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): cobble
	**Target: Contact0008** Sonar Time at Target: 10/07/2004 15:26:22 Target Capture Time Local: 01/25/06 09:51:25 Target Capture Time UTC: 01/25/06 14:51:25 Target Click Position (GEO): 42° 46.38627' N 070° 15.23334' W Target Click Position (UTM83-19): N:4736381.25 E:397421.67 Acoustic Source File: H:\EFH\ph sss\raw\line5-150m.xtf, Ping:1308 Horizontal range to target: 55.50 meters to Port side Slant range to target: 72.19 meters to Port side Event Number: 0 Line Name: line5-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge

	**Target: Contact0009** Sonar Time at Target: 10/07/2004 16:18:23 Target Capture Time Local: 01/25/06 10:19:31 Target Capture Time UTC: 01/25/06 15:19:31 Target Click Position (GEO): 42° 46.82067' N 070° 15.23074' W Target Click Position (UTM83-19): N:4737185.18 E:397437.16 Acoustic Source File: H:\EFH\ph sss\raw\line6-150m.xtf, Ping:2899 Horizontal range to target: 98.67 meters to Port side Slant range to target: 110.37 meters to Port side Event Number: 0 Line Name: line6-150m	Target Description: cobbles over coarse sand and gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): cobble
	**Target: Contact0010** Sonar Time at Target: 10/07/2004 16:13:35 Target Capture Time Local: 01/25/06 10:20:31 Target Capture Time UTC: 01/25/06 15:20:31 Target Click Position (GEO): 42° 46.38724' N 070° 15.19599' W Target Click Position (UTM83-19): N:4736382.28 E:397472.61 Acoustic Source File: H:\EFH\ph sss\raw\line6-150m.xtf, Ping:1618 Horizontal range to target: 42.07 meters to Port side Slant range to target: 53.05 meters to Port side Event Number: 0 Line Name: line6-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge

	**Target: Contact0011** Sonar Time at Target: 10/07/2004 16:13:40 Target Capture Time Local: 01/25/06 10:21:02 Target Capture Time UTC: 01/25/06 15:21:02 Target Click Position (GEO): 42° 46.39349' N 070° 15.19283' W Target Click Position (UTM83-19): N:4736393.80 E:397477.10 Acoustic Source File: H:\EFH\ph sss\raw\line6-150m.xtf, Ping:1639 Horizontal range to target: 37.52 meters to Port side Slant range to target: 49.73 meters to Port side Event Number: 0 Line Name: line6-150m	Target Description: West Pigeon Hill Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge
	**Target: Contact0012** Sonar Time at Target: 10/07/2004 16:15:15 Target Capture Time Local: 01/25/06 10:19:16 Target Capture Time UTC: 01/25/06 15:19:16 Target Click Position (GEO): 42° 46.53469' N 070° 15.12516' W Target Click Position (UTM83-19): N:4736653.76 E:397573.25 Acoustic Source File: H:\EFH\ph sss\raw\line6-150m.xtf, Ping:2062 Horizontal range to target: 53.98 meters to Stbd side Slant range to target: 68.32 meters to Stbd side Event Number: 0 Line Name: line6-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge

	**Target: Contact0013** Sonar Time at Target: 10/07/2004 16:09:01 Target Capture Time Local: 01/25/06 10:18:24 Target Capture Time UTC: 01/25/06 15:18:24 Target Click Position (GEO): 42° 45.97317' N 070° 15.10093' W Target Click Position (UTM83-19): N:4735614.02 E:397590.86 Acoustic Source File: H:\EFH\ph sss\raw\line6-150m.xtf, Ping:401 Horizontal range to target: 93.63 meters to Stbd side Slant range to target: 105.89 meters to Stbd side Event Number: 0 Line Name: line6-150m	Target Description: sand/gravel ripples Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand
	**Target: Contact0014** Sonar Time at Target: 10/07/2004 16:25:11 Target Capture Time Local: 01/25/06 10:23:34 Target Capture Time UTC: 01/25/06 15:23:34 Target Click Position (GEO): 42° 46.43020' N 070° 15.10810' W Target Click Position (UTM83-19): N:4736460.03 E:397593.64 Acoustic Source File: H:\EFH\ph sss\raw\line7-150m.xtf, Ping:1218 Horizontal range to target: 76.06 meters to Stbd side Slant range to target: 83.97 meters to Stbd side Event Number: 0 Line Name: line7-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge

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Sonar Time at Target: 10/07/2004 16:58:03
Target Capture Time Local: 01/25/06 10:24:44
Target Capture Time UTC: 01/25/06 15:24:44
Target Click Position (GEO): 42° 45.89217' N 070° 15.01483' W
Target Click Position (UTM83-19): N:4735462.37 E:397706.05
Acoustic Source File: H:\EFH\ph sss\raw\line8-150m.xtf, Ping:2800
Horizontal range to target: 88.36 meters to Stbd side
Slant range to target: 130.56 meters to Stbd side
Event Number: 0
Line Name: line8-150m</td>
<td>Target Description: N/A
Target Height =0.00 Meters
Target Length: 0.00 Meters
Target Shadow: 0.00 Meters
Target Width: 0.00 Meters
User Classification (1): muddy sand</td>
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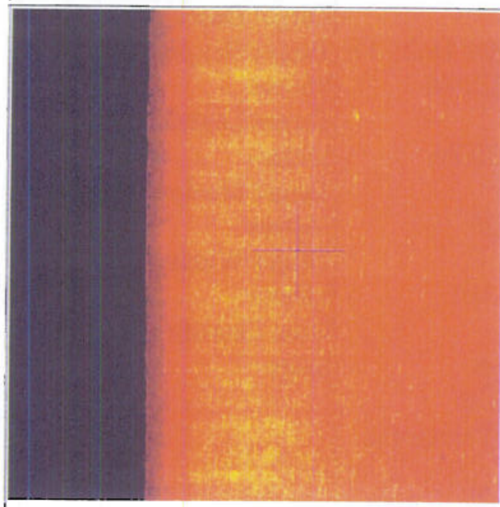
<td></td>
<td>Target: Contact0016
Sonar Time at Target: 10/07/2004 16:49:26
Target Capture Time Local: 01/25/06 10:24:09
Target Capture Time UTC: 01/25/06 15:24:09
Target Click Position (GEO): 42° 46.69930' N 070° 15.01745' W
Target Click Position (UTM83-19): N:4736956.23 E:397724.61
Acoustic Source File: H:\EFH\ph sss\raw\line8-150m.xtf, Ping:503
Horizontal range to target: 99.35 meters to Stbd side
Slant range to target: 110.11 meters to Stbd side
Event Number: 0
Line Name: line8-150m</td>
<td>Target Description: Cobbles on coarse sand and gravel
Target Height =0.00 Meters
Target Length: 0.00 Meters
Target Shadow: 0.00 Meters
Target Width: 0.00 Meters
User Classification (1): gravel</td>
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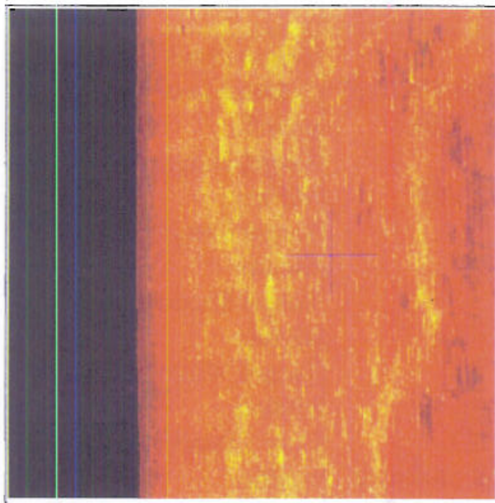
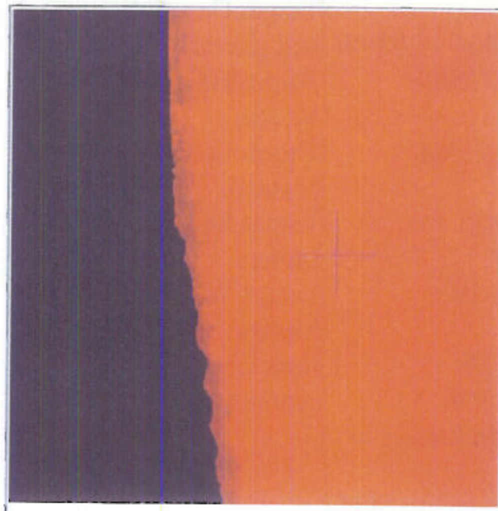
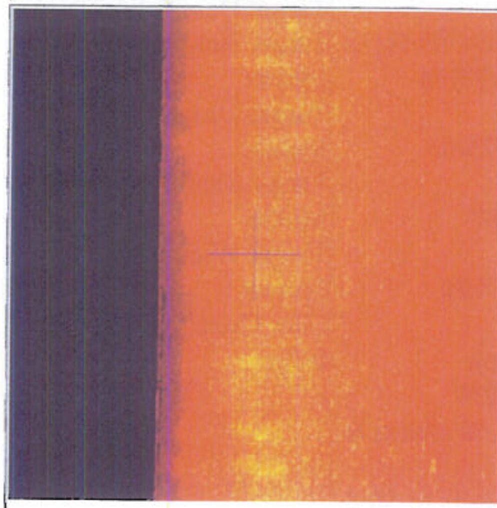
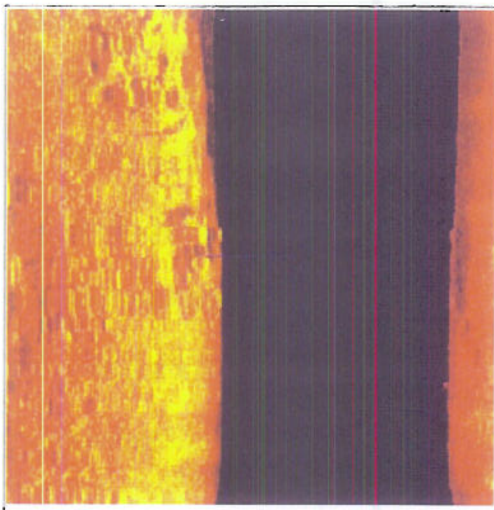
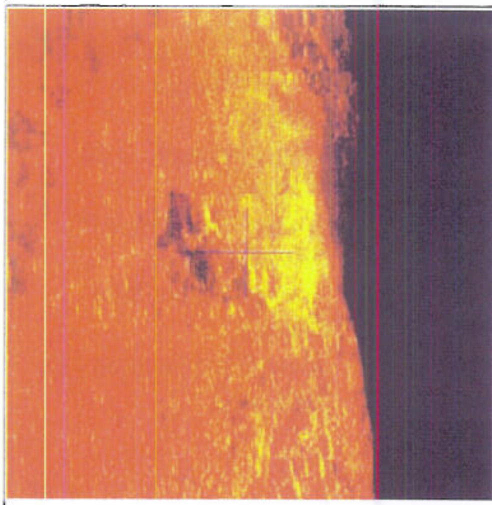
	**Target: Contact0017** Sonar Time at Target: 10/07/2004 16:38:49 Target Capture Time Local: 01/25/06 10:25:54 Target Capture Time UTC: 01/25/06 15:25:54 Target Click Position (GEO): 42° 46.30834' N 070° 14.76594' W Target Click Position (UTM83-19): N:4736227.59 E:398056.83 Acoustic Source File: H:\EFH\ph sss\raw\line9-150m.xtf, Ping:1356 Horizontal range to target: 93.58 meters to Stbd side Slant range to target: 104.28 meters to Stbd side Event Number: 0 Line Name: line9-150m	Target Description: sand and gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand
	**Target: Contact0018** Sonar Time at Target: 10/07/2004 16:41:33 Target Capture Time Local: 01/25/06 10:25:43 Target Capture Time UTC: 01/25/06 15:25:43 Target Click Position (GEO): 42° 46.56358' N 070° 14.75262' W Target Click Position (UTM83-19): N:4736699.71 E:398081.97 Acoustic Source File: H:\EFH\ph sss\raw\line9-150m.xtf, Ping:2089 Horizontal range to target: 112.68 meters to Stbd side Slant range to target: 121.58 meters to Stbd side Event Number: 0 Line Name: line9-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge

	**Target: Contact0019** Sonar Time at Target: 10/07/2004 19:36:19 Target Capture Time Local: 01/25/06 10:29:58 Target Capture Time UTC: 01/25/06 15:29:58 Target Click Position (GEO): 42° 46.13856' N 070° 14.69861' W Target Click Position (UTM83-19): N:4735912.00 E:398143.99 Acoustic Source File: H:\EFH\ph sss\raw\line11-150m.xtf, Ping:2273 Horizontal range to target: 112.73 meters to Stbd side Slant range to target: 127.81 meters to Stbd side Event Number: 0 Line Name: line11-150m	Target Description: Coarse sand with small ripples Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand
	**Target: Contact0020** Sonar Time at Target: 10/07/2004 19:28:57 Target Capture Time Local: 01/25/06 10:31:03 Target Capture Time UTC: 01/25/06 15:31:03 Target Click Position (GEO): 42° 46.78205' N 070° 14.66996' W Target Click Position (UTM83-19): N:4737102.38 E:398200.64 Acoustic Source File: H:\EFH\ph sss\raw\line11-150m.xtf, Ping:313 Horizontal range to target: 81.38 meters to Stbd side Slant range to target: 95.06 meters to Stbd side Event Number: 0 Line Name: line11-150m	Target Description: Cobbles over sand and gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): cobble

	**Target: Contact0021** Sonar Time at Target: 10/07/2004 19:32:56 Target Capture Time Local: 01/25/06 10:30:38 Target Capture Time UTC: 01/25/06 15:30:38 Target Click Position (GEO): 42° 46.43007' N 070° 14.59296' W Target Click Position (UTM83-19): N:4736449.39 E:398296.00 Acoustic Source File: H:\EFH\ph sss\raw\line11-150m.xtf, Ping:1375 Horizontal range to target: 30.14 meters to Port side Slant range to target: 49.48 meters to Port side Event Number: 0 Line Name: line11-150m	Target Description: East Pigeon Hill Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge
	**Target: Contact0022** Sonar Time at Target: 10/07/2004 17:44:12 Target Capture Time Local: 01/25/06 10:31:43 Target Capture Time UTC: 01/25/06 15:31:43 Target Click Position (GEO): 42° 46.37632' N 070° 14.55960' W Target Click Position (UTM83-19): N:4736349.25 E:398340.03 Acoustic Source File: H:\EFH\ph sss\raw\line12-150m.xtf, Ping:1005 Horizontal range to target: 73.43 meters to Port side Slant range to target: 83.28 meters to Port side Event Number: 0 Line Name: line12-150m	Target Description: Spire outcrop on East Pigeon Hill Target Height =4.14 Meters Target Length: 31.69 Meters Target Shadow: 13.17 Meters Target Width: 11.90 Meters User Classification (1): ledge

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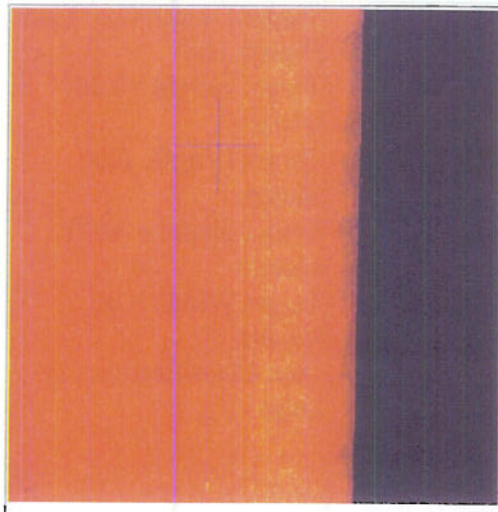
<td></td>
<td>Target: Contact0023
Sonar Time at Target: 10/07/2004 17:49:15
Target Capture Time Local: 01/25/06 10:33:30
Target Capture Time UTC: 01/25/06 15:33:30
Target Click Position (GEO): 42° 46.84129' N 070° 14.56870' W
Target Click Position (UTM83-19): N:4737209.97 E:398340.30
Acoustic Source File: H:\EFH\ph sss\raw\line12-150m.xtf, Ping:2349
Horizontal range to target: 96.58 meters to Port side
Slant range to target: 108.21 meters to Port side
Event Number: 0
Line Name: line12-150m</td>
<td>Target Description: Sand and gravel with fine ripples
Target Height =0.00 Meters
Target Length: 0.00 Meters
Target Shadow: 0.00 Meters
Target Width: 0.00 Meters
User Classification (1): coarse sand</td>
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<td>Target: Contact0024
Sonar Time at Target: 10/07/2004 17:40:44
Target Capture Time Local: 01/25/06 10:34:00
Target Capture Time UTC: 01/25/06 15:34:00
Target Click Position (GEO): 42° 46.05214' N 070° 14.44410' W
Target Click Position (UTM83-19): N:4735746.94 E:398488.69
Acoustic Source File: H:\EFH\ph sss\raw\line12-150m.xtf, Ping:81
Horizontal range to target: 89.51 meters to Stbd side
Slant range to target: 125.46 meters to Stbd side
Event Number: 0
Line Name: line12-150m</td>
<td>Target Description: N/A
Target Height =0.00 Meters
Target Length: 0.00 Meters
Target Shadow: 0.00 Meters
Target Width: 0.00 Meters
User Classification (1): fine sand</td>
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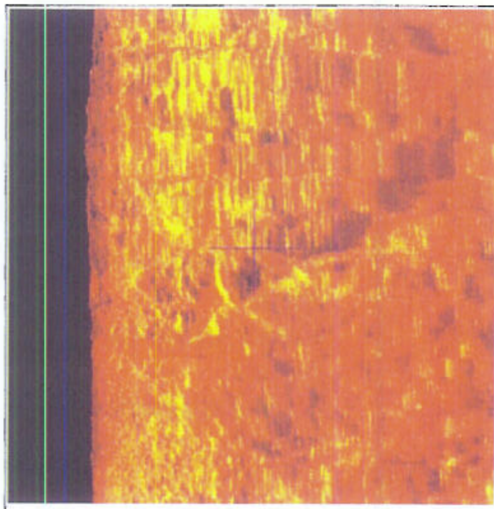
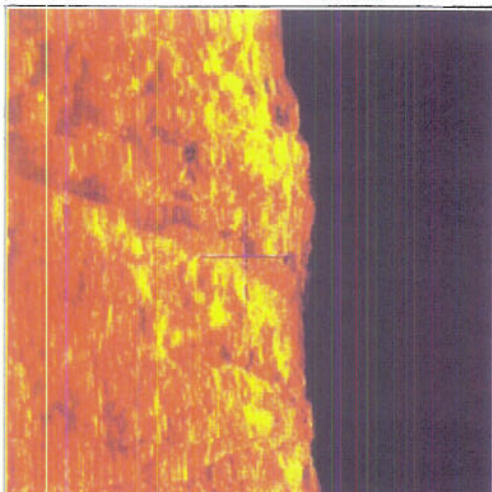
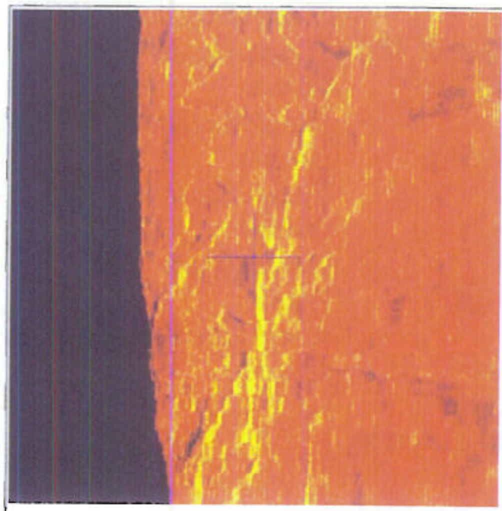
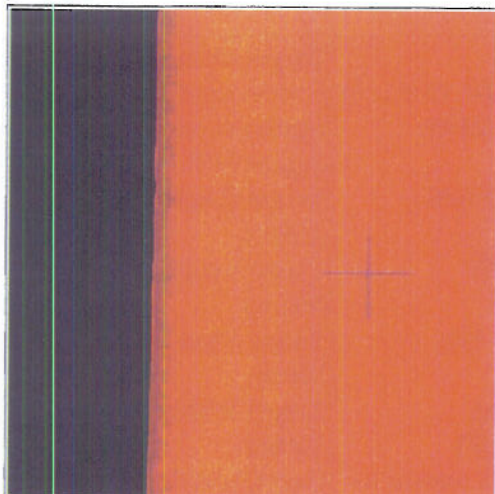
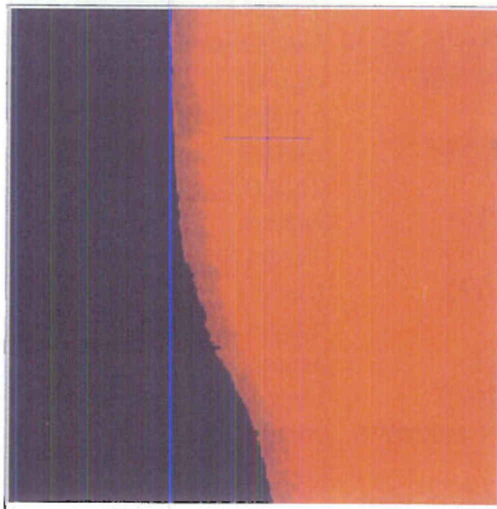
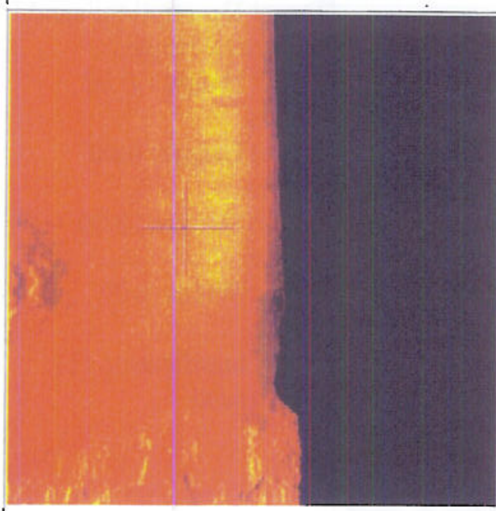
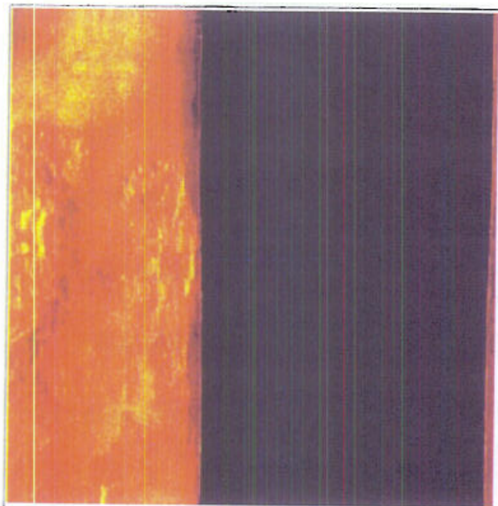
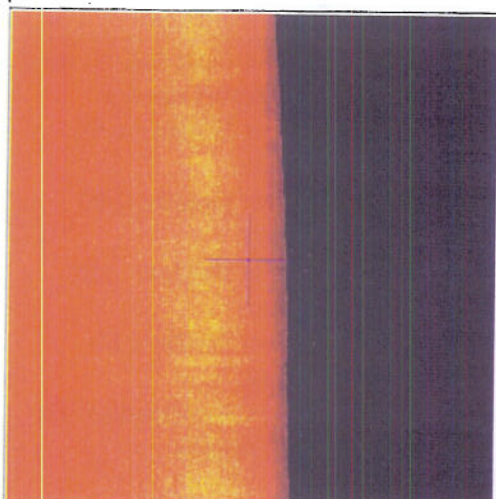
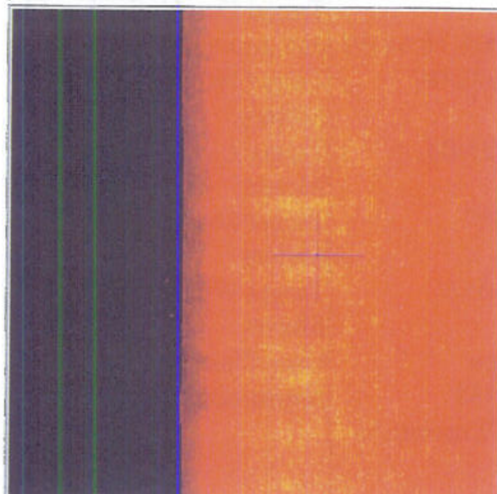
	**Target: Contact0025** Sonar Time at Target: 10/07/2004 17:45:09 Target Capture Time Local: 01/25/06 10:32:31 Target Capture Time UTC: 01/25/06 15:32:31 Target Click Position (GEO): 42° 46.46269' N 070° 14.43989' W Target Click Position (UTM83-19): N:4736506.70 E:398505.60 Acoustic Source File: H:\EFH\ph sss\raw\line12-150m.xtf, Ping:1259 Horizontal range to target: 85.81 meters to Stbd side Slant range to target: 90.37 meters to Stbd side Event Number: 0 Line Name: line12-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge
	**Target: Contact0026** Sonar Time at Target: 10/07/2004 19:19:54 Target Capture Time Local: 01/25/06 10:34:33 Target Capture Time UTC: 01/25/06 15:34:33 Target Click Position (GEO): 42° 46.40039' N 070° 14.43762' W Target Click Position (UTM83-19): N:4736391.34 E:398507.00 Acoustic Source File: H:\EFH\ph sss\raw\line13-150m.xtf, Ping:950 Horizontal range to target: 60.01 meters to Port side Slant range to target: 71.43 meters to Port side Event Number: 0 Line Name: line13-150m	Target Description: Crevice on East Pigeon Hill Target Height =4.24 Meters Target Length: 105.81 Meters Target Shadow: 10.22 Meters Target Width: 12.37 Meters User Classification (1): ledge

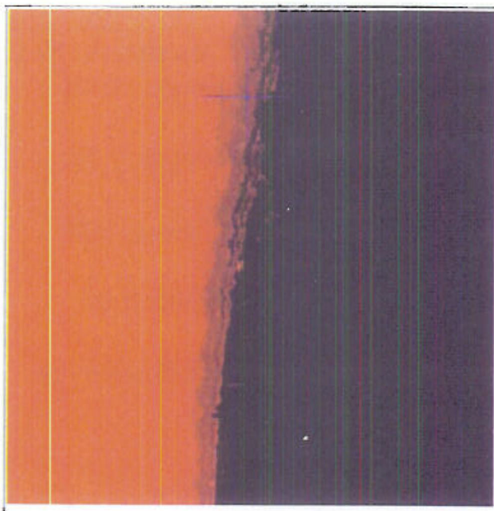
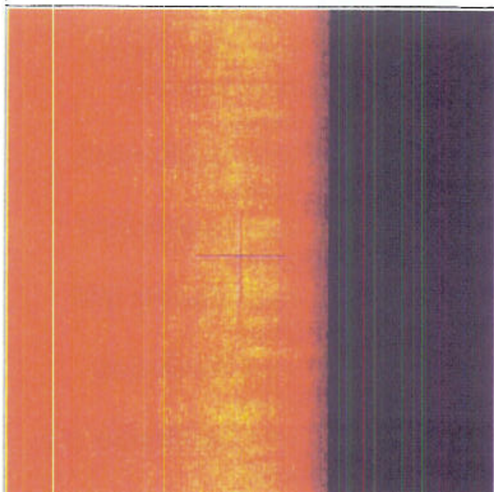
	**Target: Contact0027** Sonar Time at Target: 10/07/2004 17:57:31 Target Capture Time Local: 01/25/06 10:37:53 Target Capture Time UTC: 01/25/06 15:37:53 Target Click Position (GEO): 42° 46.54819' N 070° 14.33383' W Target Click Position (UTM83-19): N:4736662.81 E:398652.53 Acoustic Source File: H:\EFH\ph sss\raw\line14-150m.xtf, Ping:981 Horizontal range to target: 68.20 meters to Stbd side Slant range to target: 74.18 meters to Stbd side Event Number: 0 Line Name: line14-150m	Target Description: Bedrock striations Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge
	**Target: Contact0028** Sonar Time at Target: 10/07/2004 19:23:06 Target Capture Time Local: 01/25/06 10:35:42 Target Capture Time UTC: 01/25/06 15:35:42 Target Click Position (GEO): 42° 46.69793' N 070° 14.33661' W Target Click Position (UTM83-19): N:4736940.00 E:398652.82 Acoustic Source File: H:\EFH\ph sss\raw\line13-150m.xtf, Ping:1799 Horizontal range to target: 71.64 meters to Stbd side Slant range to target: 86.71 meters to Stbd side Event Number: 0 Line Name: line13-150m	Target Description: Fine to coarse sand at base of Pigeon Hill Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): fine sand

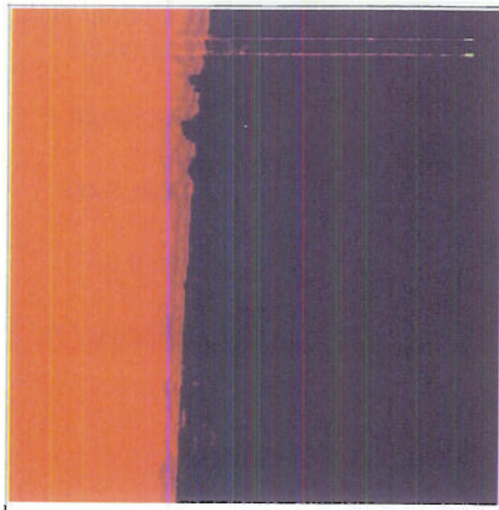
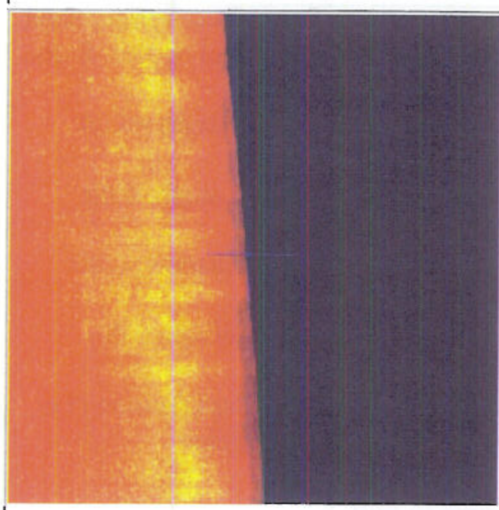
	**Target: Contact0029** Sonar Time at Target: 10/07/2004 19:23:56 Target Capture Time Local: 01/25/06 10:36:15 Target Capture Time UTC: 01/25/06 15:36:15 Target Click Position (GEO): 42° 46.77238' N 070° 14.32759' W Target Click Position (UTM83-19): N:4737077.61 E:398667.14 Acoustic Source File: H:\EFH\ph sss\raw\line13-150m.xtf, Ping:2025 Horizontal range to target: 86.11 meters to Stbd side Slant range to target: 98.17 meters to Stbd side Event Number: 0 Line Name: line13-150m	Target Description: Coarse sand and gravel ripples Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand
	**Target: Contact0030** Sonar Time at Target: 10/07/2004 19:06:22 Target Capture Time Local: 01/25/06 10:38:35 Target Capture Time UTC: 01/25/06 15:38:35 Target Click Position (GEO): 42° 46.84221' N 070° 14.25672' W Target Click Position (UTM83-19): N:4737205.43 E:398765.65 Acoustic Source File: H:\EFH\ph sss\raw\line15-150m.xtf, Ping:120 Horizontal range to target: 124.99 meters to Stbd side Slant range to target: 134.67 meters to Stbd side Event Number: 0 Line Name: line15-150m	Target Description: sand and gravel ripples Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand

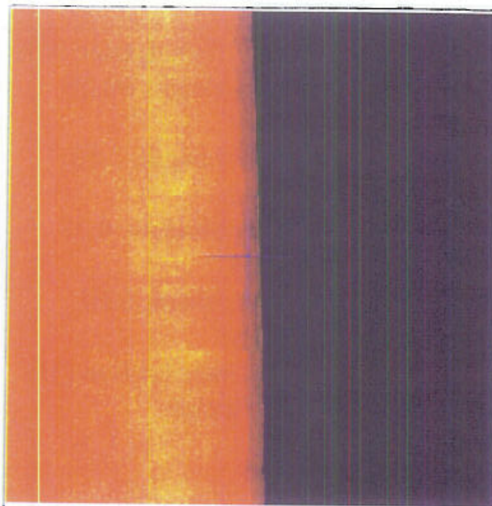
	**Target: Contact0031** Sonar Time at Target: 10/07/2004 19:13:53 Target Capture Time Local: 01/25/06 10:39:01 Target Capture Time UTC: 01/25/06 15:39:01 Target Click Position (GEO): 42° 46.15360' N 070° 14.24127' W Target Click Position (UTM83-19): N:4735930.66 E:398768.02 Acoustic Source File: H:\EFH\ph sss\raw\line15-150m.xtf, Ping:2124 Horizontal range to target: 88.94 meters to Stbd side Slant range to target: 122.35 meters to Stbd side Event Number: 0 Line Name: line15-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): flat sand
	**Target: Contact0032** Sonar Time at Target: 10/07/2004 17:55:50 Target Capture Time Local: 01/25/06 10:37:17 Target Capture Time UTC: 01/25/06 15:37:17 Target Click Position (GEO): 42° 46.70869' N 070° 14.22421' W Target Click Position (UTM83-19): N:4736957.69 E:398806.33 Acoustic Source File: H:\EFH\ph sss\raw\line14-150m.xtf, Ping:534 Horizontal range to target: 51.81 meters to Port side Slant range to target: -74.39 meters to Port side Event Number: 0 Line Name: line14-150m	Target Description: Coarse sand and gravel ripples at base of East Pigeon Hill Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand

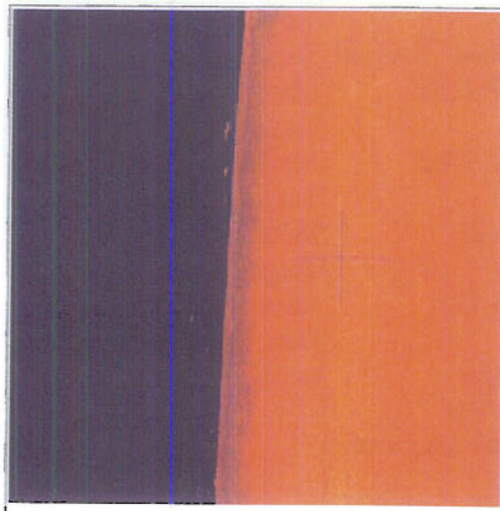
	**Target: Contact0033** Sonar Time at Target: 10/07/2004 18:10:31 Target Capture Time Local: 01/25/06 10:39:33 Target Capture Time UTC: 01/25/06 15:39:33 Target Click Position (GEO): 42° 46.69802' N 070° 14.08331' W Target Click Position (UTM83-19): N:4736935.10 E:398998.15 Acoustic Source File: H:\EFH\ph sss\raw\line16-150m.xtf, Ping:1543 Horizontal range to target: 32.70 meters to Port side Slant range to target: 60.39 meters to Port side Event Number: 0 Line Name: line16-150m	Target Description: Ledge at edge of East Pigeon Hill surrounded by sand Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): ledge
	**Target: Contact0034** Sonar Time at Target: 10/07/2004 18:56:40 Target Capture Time Local: 01/25/06 10:41:42 Target Capture Time UTC: 01/25/06 15:41:42 Target Click Position (GEO): 42° 46.30193' N 070° 14.00599' W Target Click Position (UTM83-19): N:4736200.48 E:399092.86 Acoustic Source File: H:\EFH\ph sss\raw\line17-150m.xtf, Ping:438 Horizontal range to target: 71.92 meters to Port side Slant range to target: 93.24 meters to Port side Event Number: 0 Line Name: line17-150m	Target Description: sand and gravel ripples Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand

	**Target: Contact0035** Sonar Time at Target: 10/07/2004 19:02:28 Target Capture Time Local: 01/25/06 10:41:59 Target Capture Time UTC: 01/25/06 15:41:59 Target Click Position (GEO): 42° 46.84755' N 070° 13.86263' W Target Click Position (UTM83-19): N:4737207.44 E:399303.07 Acoustic Source File: H:\EFH\ph sss\raw\line17-150m.xtf, Ping:1983 Horizontal range to target: 117.67 meters to Stbd side Slant range to target: 129.64 meters to Stbd side Event Number: 0 Line Name: line17-150m	Target Description: sand and gravel ripples Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): coarse sand
	**Target: Contact0036** Sonar Time at Target: 10/07/2004 18:47:02 Target Capture Time Local: 01/25/06 10:43:44 Target Capture Time UTC: 01/25/06 15:43:44 Target Click Position (GEO): 42° 46.79539' N 070° 13.80763' W Target Click Position (UTM83-19): N:4737109.83 E:399376.64 Acoustic Source File: H:\EFH\ph sss\raw\line19-150m.xtf, Ping:217 Horizontal range to target: 106.54 meters to Stbd side Slant range to target: 122.44 meters to Stbd side Event Number: 0 Line Name: line19-150m	Target Description: sand and gravel ripples Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): sand ripples

	**Target: Contact0037** Sonar Time at Target: 10/07/2004 18:22:17 Target Capture Time Local: 01/25/06 10:43:05 Target Capture Time UTC: 01/25/06 15:43:05 Target Click Position (GEO): 42° 46.22398' N 070° 13.78374' W Target Click Position (UTM83-19): N:4736051.80 E:399393.80 Acoustic Source File: H:\EFH\ph sss\raw\line18-150m.xtf, Ping:1909 Horizontal range to target: 85.12 meters to Port side Slant range to target: 127.89 meters to Port side Event Number: 0 Line Name: line18-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): flat sand
	**Target: Contact0038** Sonar Time at Target: 10/07/2004 18:16:27 Target Capture Time Local: 01/25/06 10:42:39 Target Capture Time UTC: 01/25/06 15:42:39 Target Click Position (GEO): 42° 46.75831' N 070° 13.77743' W Target Click Position (UTM83-19): N:4737040.59 E:399416.81 Acoustic Source File: H:\EFH\ph sss\raw\line18-150m.xtf, Ping:353 Horizontal range to target: 86.97 meters to Port side Slant range to target: 104.64 meters to Port side Event Number: 0 Line Name: line18-150m	Target Description: sand and gravel ripples. Some cobbles Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): sand ripples

	**Target: Contact0039** Sonar Time at Target: 10/07/2004 18:52:43 Target Capture Time Local: 01/25/06 10:44:02 Target Capture Time UTC: 01/25/06 15:44:02 Target Click Position (GEO): 42° 46.27961' N 070° 13.68268' W Target Click Position (UTM83-19): N:4736152.75 E:399533.10 Acoustic Source File: H:\EFH\ph sss\raw\line19-150m.xtf, Ping:1728 Horizontal range to target: 73.94 meters to Port side Slant range to target: 122.52 meters to Port side Event Number: 0 Line Name: line19-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): flat sand
	**Target: Contact0040** Sonar Time at Target: 10/07/2004 18:28:51 Target Capture Time Local: 01/25/06 10:44:29 Target Capture Time UTC: 01/25/06 15:44:29 Target Click Position (GEO): 42° 46.53165' N 070° 13.67770' W Target Click Position (UTM83-19): N:4736619.12 E:399546.67 Acoustic Source File: H:\EFH\ph sss\raw\line20-150m.xtf, Ping:773 Horizontal range to target: 76.48 meters to Port side Slant range to target: 109.58 meters to Port side Event Number: 0 Line Name: line20-150m	Target Description: Gravel and some cobbles Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): gravel

	**Target: Contact0041** Sonar Time at Target: 10/07/2004 18:41:40 Target Capture Time Local: 01/25/06 10:45:16 Target Capture Time UTC: 01/25/06 15:45:16 Target Click Position (GEO): 42° 46.70668' N 070° 13.56861' W Target Click Position (UTM83-19): N:4736940.89 E:399700.11 Acoustic Source File: H:\EFH\ph sss\raw\line21-150m.xtf, Ping:400 Horizontal range to target: 76.43 meters to Port side Slant range to target: 105.60 meters to Port side Event Number: 0 Line Name: line21-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): gravel
	**Target: Contact0042** Sonar Time at Target: 10/07/2004 18:28:55 Target Capture Time Local: 01/25/06 10:44:50 Target Capture Time UTC: 01/25/06 15:44:50 Target Click Position (GEO): 42° 46.54336' N 070° 13.53590' W Target Click Position (UTM83-19): N:4736637.98 E:399740.33 Acoustic Source File: H:\EFH\ph sss\raw\line20-150m.xtf, Ping:792 Horizontal range to target: 116.72 meters to Stbd side Slant range to target: 139.91 meters to Stbd side Event Number: 0 Line Name: line20-150m	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): flat sand



Target: Contact0043
Sonar Time at Target: 10/07/2004 18:41:23
Target Capture Time Local: 01/25/06 10:45:26
Target Capture Time UTC: 01/25/06 15:45:26
Target Click Position (GEO): 42° 46.67678' N 070° 13.42878' W
Target Click Position (UTM83-19): N:4736882.79 E:399889.95
Acoustic Source File: H:\EFH\ph sss\raw\line21-150m.xtf, Ping:325
Horizontal range to target: 114.07 meters to Stbd side
Slant range to target: 136.44 meters to Stbd side
Event Number: 0
Line Name: line21-150m

Target Description: N/A
Target Height =0.00 Meters
Target Length: 0.00 Meters
Target Shadow: 0.00 Meters
Target Width: 0.00 Meters
User Classification (1): sand ripples

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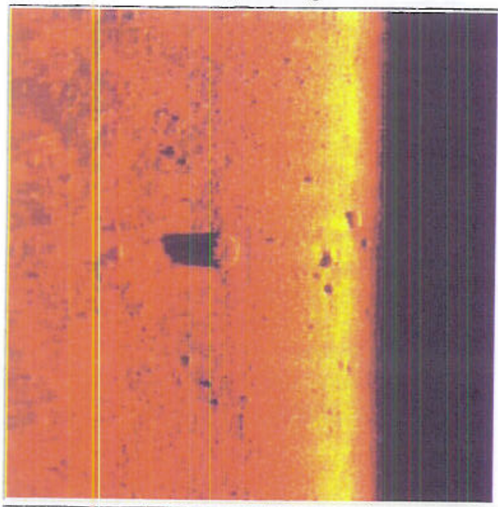
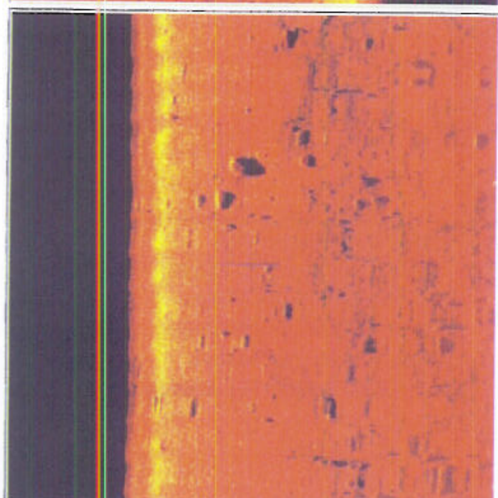
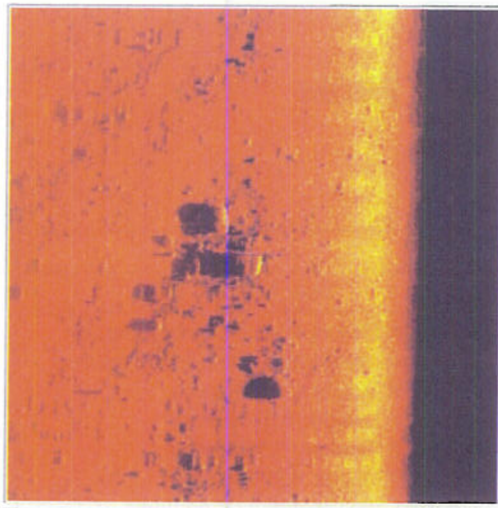
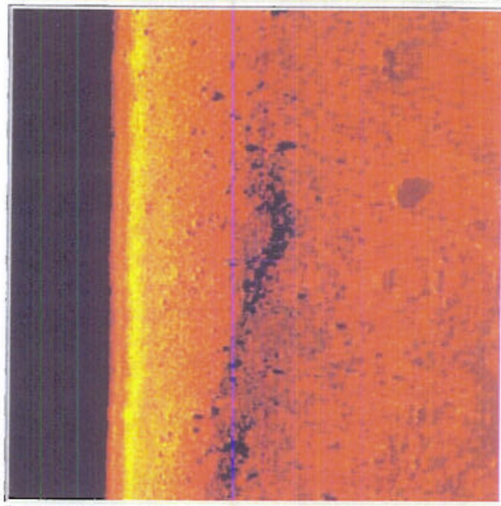
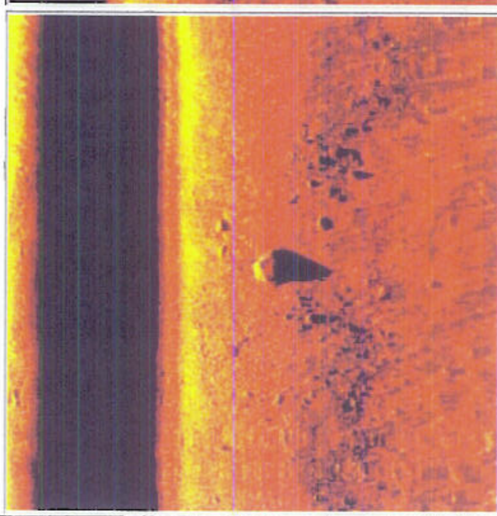
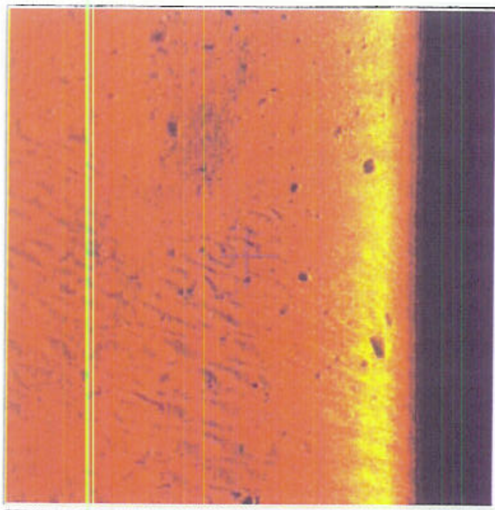
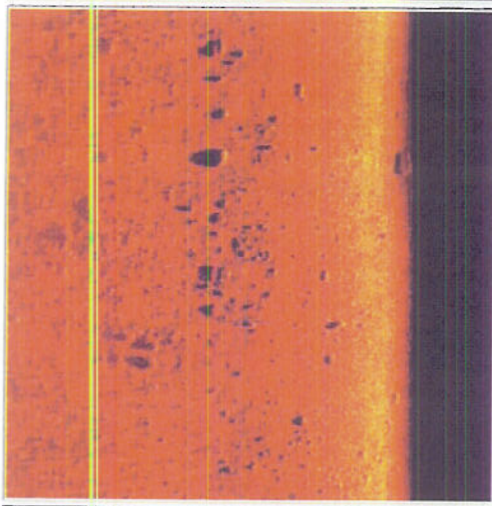
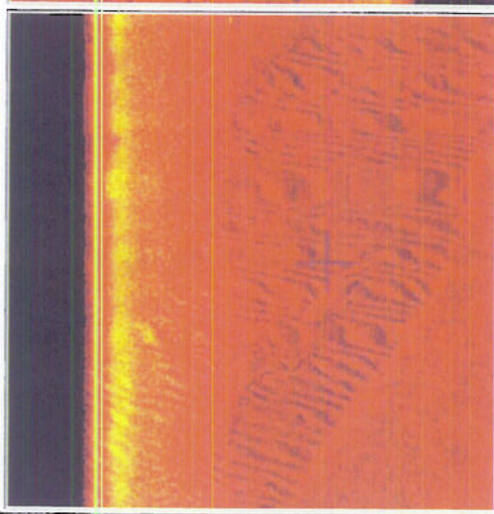
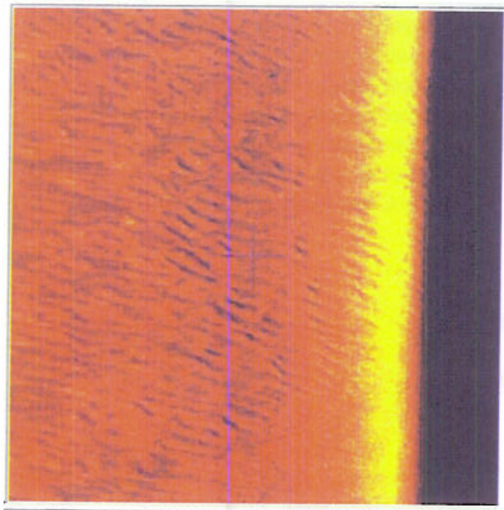
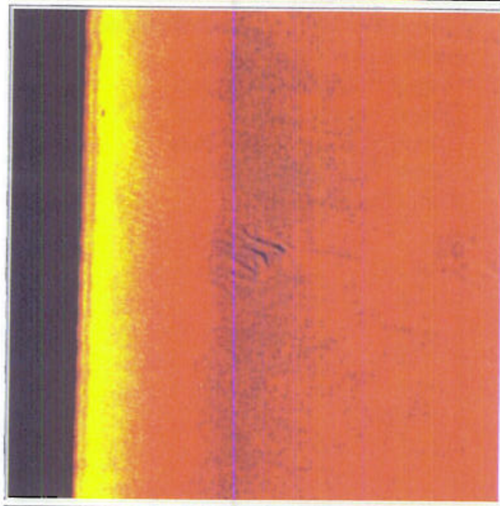
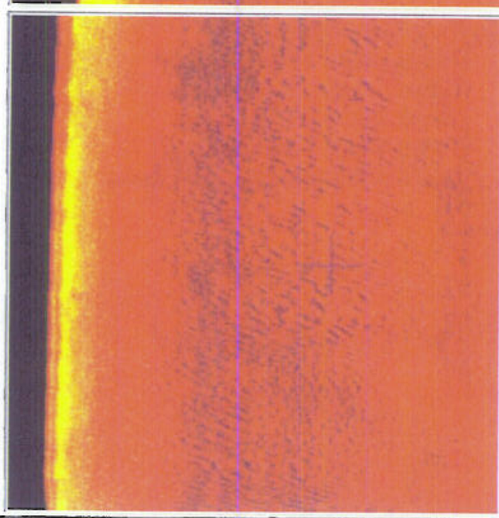
APPENDIX B

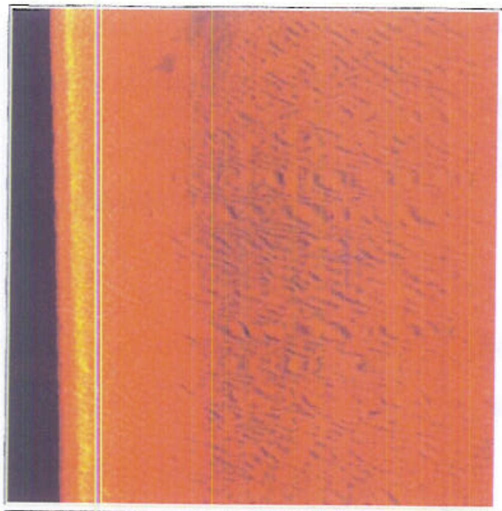
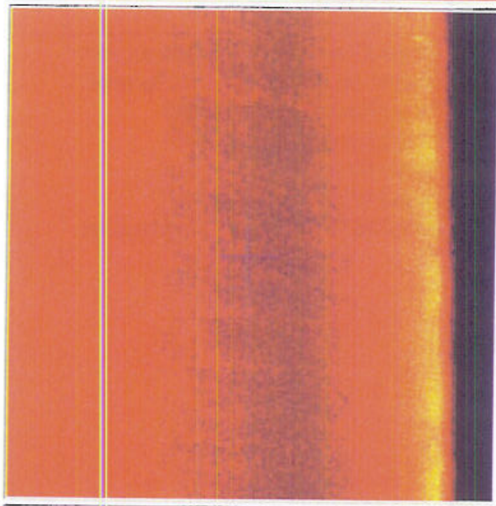
REPRESENTATIVE SIDE SCAN SONAR IMAGERY FROM STELLWAGEN / LONG BANK 100 KHZ TOWED SYSTEM

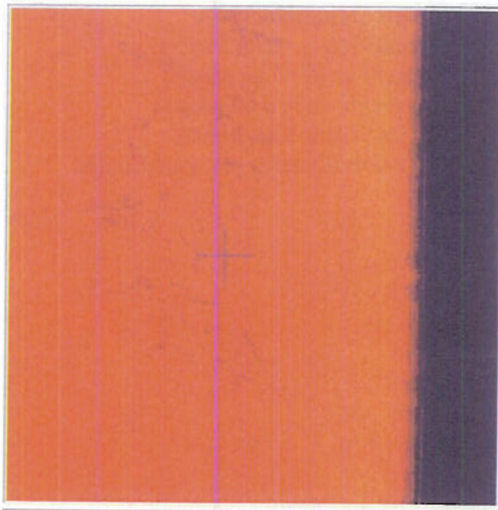
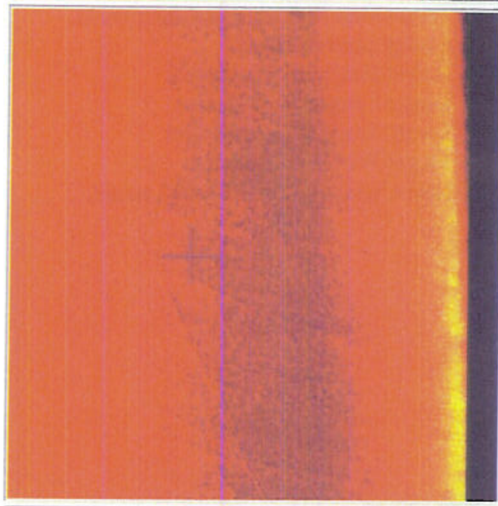
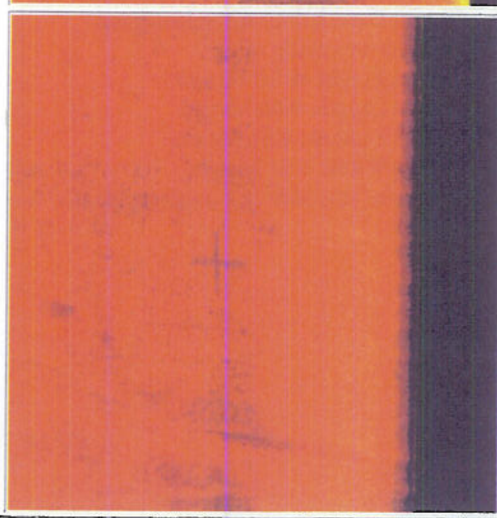
Target Elements		
Target Image	**Target Info**	**User Entered Info**
	**Target: Contact0002** Sonar Time at Target: 07/30/2004 15:32:17 Target Capture Time Local: 01/25/06 08:24:28 Target Capture Time UTC: 01/25/06 13:24:28 Target Click Position (GEO): 42° 13.10531' N 070° 32.88445' W Target Click Position (UTM83-19): N:4675187.85 E:372230.01 Acoustic Source File: I:\EFH\sw sss\raw\LINE___R.XTF, Ping:1642 Horizontal range to target: 33.94 meters to Port side Slant range to target: 35.96 meters to Port side Event Number: 0 Line Name: LINE___R	Target Description: Large boulder on gravel/cobble adjacent to ledge outcrop Target Height =2.54 Meters Target Length: 7.62 Meters Target Shadow: 9.96 Meters Target Width: 4.29 Meters User Classification (1): boulders
	**Target: Contact0003** Sonar Time at Target: 07/30/2004 13:19:41 Target Capture Time Local: 01/24/06 18:20:27 Target Capture Time UTC: 01/24/06 23:20:27 Target Click Position (GEO): 42° 13.18476' N 070° 32.80959' W Target Click Position (UTM83-19): N:4675333.00 E:372335.66 Acoustic Source File: I:\EFH\sw sss\raw\LINE___B.XTF, Ping:1644 Horizontal range to target: 34.14 meters to Stbd side Slant range to target: 36.85 meters to Stbd side Event Number: 0 Line Name: LINE___B	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): boulders

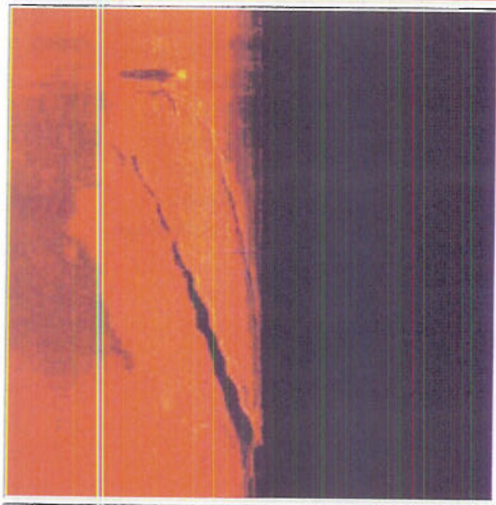
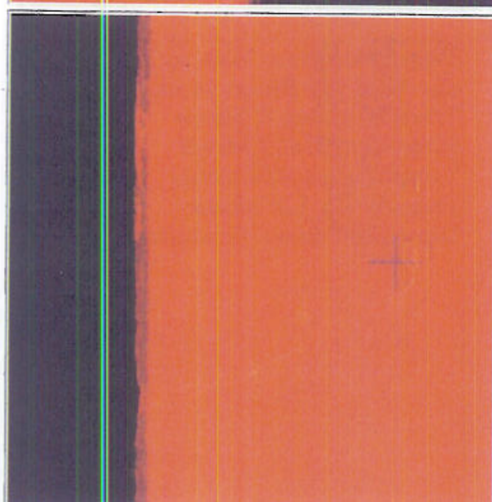
	**Target: Contact0004** Sonar Time at Target: 07/30/2004 13:20:59 Target Capture Time Local: 01/24/06 18:20:55 Target Capture Time UTC: 01/24/06 23:20:55 Target Click Position (GEO): 42° 13.24899' N 070° 32.72764' W Target Click Position (UTM83-19): N:4675449.83 E:372450.54 Acoustic Source File: I:\EFH\sw sss\raw\LINE___B.XTF, Ping:2341 Horizontal range to target: 42.35 meters to Port side Slant range to target: 44.87 meters to Port side Event Number: 0 Line Name: LINE___B	Target Description: Unknown classification. Field of three reflectors with similar dimensions and shape (roughly rectangular) amongst boulder cobble field. Target Height =2.64 Meters Target Length: 4.96 Meters Target Shadow: 9.11 Meters Target Width: 2.32 Meters User Classification (1):
	**Target: Contact0005** Sonar Time at Target: 07/30/2004 16:31:38 Target Capture Time Local: 01/25/06 08:29:33 Target Capture Time UTC: 01/25/06 13:29:33 Target Click Position (GEO): 42° 13.13371' N 070° 32.49449' W Target Click Position (UTM83-19): N:4675230.68 E:372767.40 Acoustic Source File: I:\EFH\sw sss\raw\LINE___Y.XTF, Ping:665 Horizontal range to target: 35.91 meters to Stbd side Slant range to target: 37.77 meters to Stbd side Event Number: 0 Line Name: LINE___Y	Target Description: Cobbles and boulders at ledge outcrop Target Height >=0.57 Meters Target Length: 32.89 Meters Target Shadow: 2.02 Meters Target Width: 10.09 Meters User Classification (1): cobble
	**Target: Contact0006** Sonar Time at Target: 07/30/2004 15:52:25 Target Capture Time Local: 01/24/06 18:07:29 Target Capture Time UTC: 01/24/06 23:07:29 Target Click Position (GEO): 42° 13.17641' N 070° 32.43703' W Target Click Position (UTM83-19): N:4675308.27 E:372847.87 Acoustic Source File: I:\EFH\sw sss\raw\LINE___S.XTF, Ping:5703 Horizontal range to target: 26.61 meters to Stbd side Slant range to target: 29.01 meters to Stbd side Event Number: 0 Line Name: LINE___S	Target Description: N/A Target Height >=3.15 Meters Target Length: 7.04 Meters Target Shadow: 11.09 Meters Target Width: 3.81 Meters User Classification (1): boulders

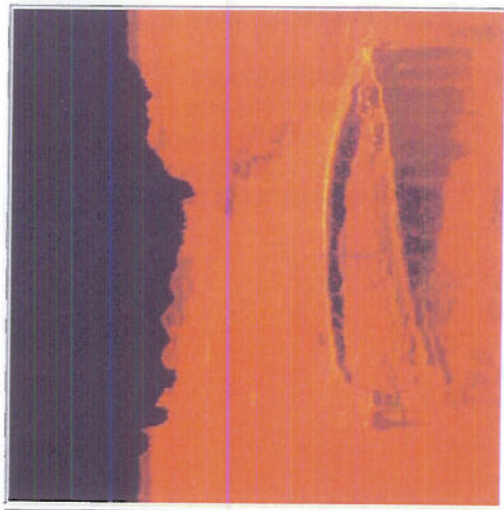
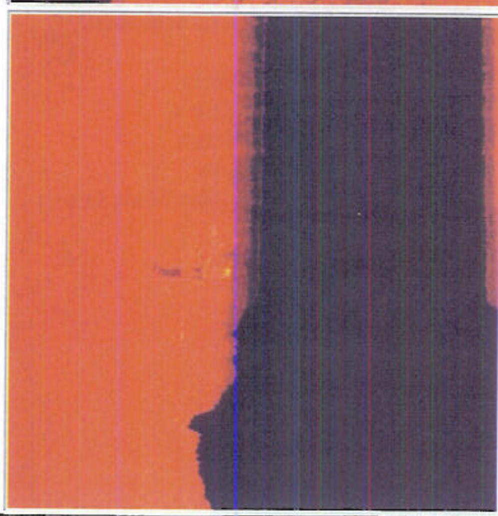
	**Target: Contact0007** Sonar Time at Target: 07/30/2004 15:26:20 Target Capture Time Local: 01/25/06 08:23:11 Target Capture Time UTC: 01/25/06 13:23:11 Target Click Position (GEO): 42° 13.22326' N 070° 32.43064' W Target Click Position (UTM83-19): N:4675394.81 E:372858.23 Acoustic Source File: I:\EFH\sw sss\raw\LINE___Q.XTF, Ping:2351 Horizontal range to target: 41.38 meters to Port side Slant range to target: 43.33 meters to Port side Event Number: 0 Line Name: LINE___Q	Target Description: Cobbles and boulders on sandy gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): cobble
	**Target: Contact0008** Sonar Time at Target: 07/30/2004 16:58:28 Target Capture Time Local: 01/24/06 18:17:20 Target Capture Time UTC: 01/24/06 23:17:20 Target Click Position (GEO): 42° 13.12542' N 070° 32.34167' W Target Click Position (UTM83-19): N:4675211.53 E:372977.34 Acoustic Source File: I:\EFH\sw sss\raw\LINE___AB.XTF, Ping:170 Horizontal range to target: 38.23 meters to Port side Slant range to target: 39.81 meters to Port side Event Number: 0 Line Name: LINE___AB	Target Description: Filed of boulders and cobbles over sandy gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1):
	**Target: Contact0009** Sonar Time at Target: 07/30/2004 15:23:40 Target Capture Time Local: 01/25/06 08:22:30 Target Capture Time UTC: 01/25/06 13:22:30 Target Click Position (GEO): 42° 13.32748' N 070° 32.25002' W Target Click Position (UTM83-19): N:4675583.20 E:373110.15 Acoustic Source File: I:\EFH\sw sss\raw\LINE___Q.XTF, Ping:930 Horizontal range to target: 55.57 meters to Stbd side Slant range to target: 57.35 meters to Stbd side Event Number: 0 Line Name: LINE___Q	Target Description: N/A Target Height >=0.28 Meters Target Length: 39.69 Meters Target Shadow: 1.16 Meters Target Width: 1.48 Meters User Classification (1): sand waves

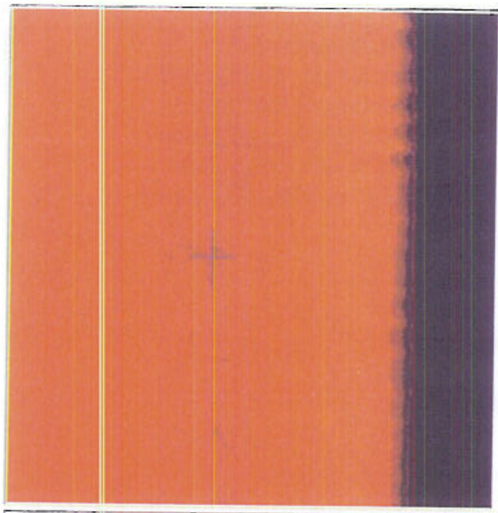
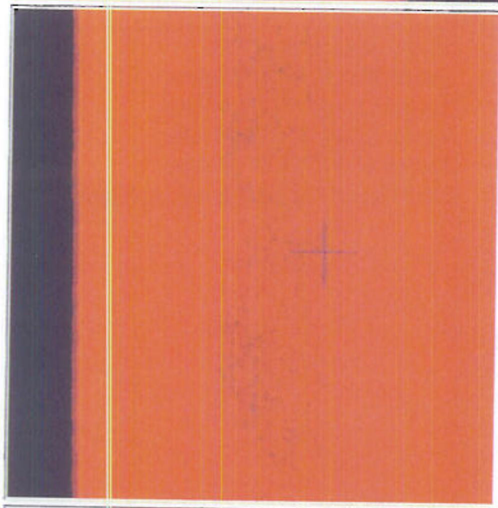
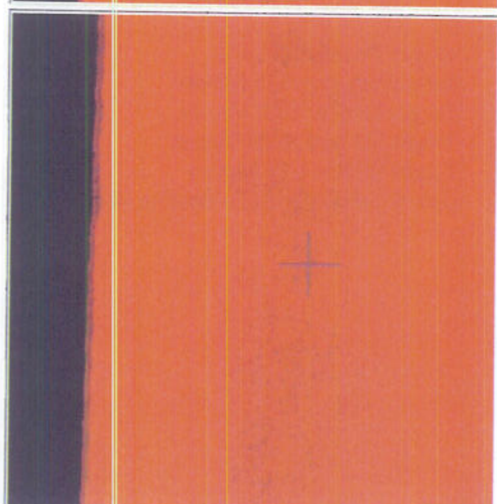
	**Target: Contact0010** Sonar Time at Target: 07/30/2004 16:28:06 Target Capture Time Local: 01/25/06 08:28:40 Target Capture Time UTC: 01/25/06 13:28:40 Target Click Position (GEO): 42° 13.18347' N 070° 32.18169' W Target Click Position (UTM83-19): N:4675315.01 E:373199.35 Acoustic Source File: I:\EFH\sw sss\raw\LINE___W.XTF, Ping:6677 Horizontal range to target: 38.49 meters to Port side Slant range to target: 39.62 meters to Port side Event Number: 0 Line Name: LINE___W	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): sand waves
	**Target: Contact0011** Sonar Time at Target: 07/30/2004 15:21:09 Target Capture Time Local: 01/25/06 08:21:20 Target Capture Time UTC: 01/25/06 13:21:20 Target Click Position (GEO): 42° 13.37492' N 070° 32.05579' W Target Click Position (UTM83-19): N:4675666.19 E:373378.91 Acoustic Source File: I:\EFH\sw sss\raw\LINE___P.XTF, Ping:1371 Horizontal range to target: 37.41 meters to Stbd side Slant range to target: 38.24 meters to Stbd side Event Number: 0 Line Name: LINE___P	Target Description: N/A Target Height >=0.22 Meters Target Length: 7.42 Meters Target Shadow: 1.24 Meters Target Width: 1.87 Meters User Classification (1): gravel ridges
	**Target: Contact0012** Sonar Time at Target: 07/30/2004 15:18:11 Target Capture Time Local: 01/25/06 08:19:48 Target Capture Time UTC: 01/25/06 13:19:48 Target Click Position (GEO): 42° 13.44235' N 070° 31.83755' W Target Click Position (UTM83-19): N:4675785.57 E:373681.35 Acoustic Source File: I:\EFH\sw sss\raw\LINE___O.XTF, Ping:2633 Horizontal range to target: 55.81 meters to Stbd side Slant range to target: 56.33 meters to Stbd side Event Number: 0 Line Name: LINE___O	Target Description: Sand ripples at transition from muddy sad/gravel substrate to sand over ledge Target Height =0.18 Meters Target Length: 0.00 Meters Target Shadow: 1.39 Meters Target Width: 0.93 Meters User Classification (1): sand ripples

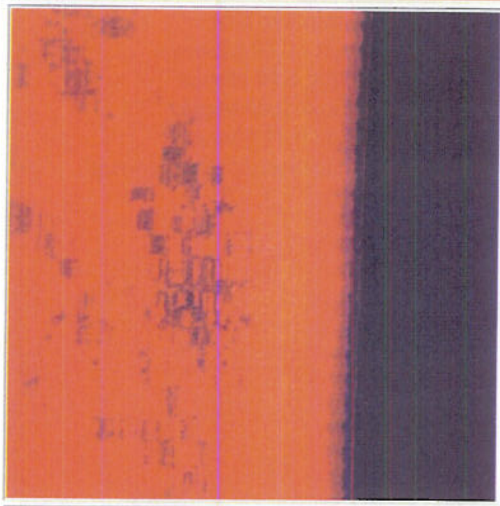
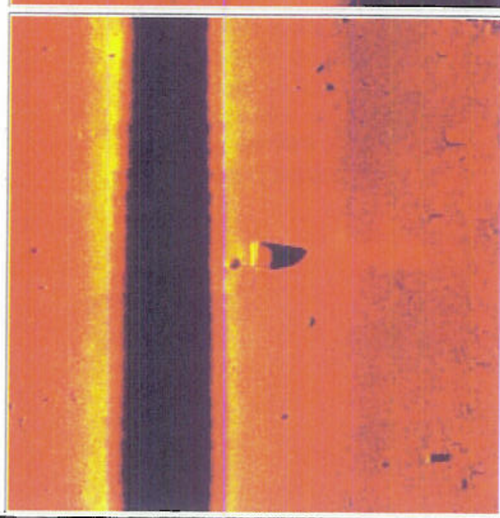
	**Target: Contact0013** Sonar Time at Target: 07/30/2004 17:10:51 Target Capture Time Local: 01/24/06 18:19:43 Target Capture Time UTC: 01/24/06 23:19:43 Target Click Position (GEO): 42° 13.29953' N 070° 31.48897' W Target Click Position (UTM83-19): N:4675512.67 E:374156.08 Acoustic Source File: I:\EFH\sw sss\raw\LINE___AE.XTF, Ping:1444 Horizontal range to target: 58.85 meters to Stbd side Slant range to target: 59.50 meters to Stbd side Event Number: 0 Line Name: LINE___AE	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): sand ripples
	**Target: Contact0014** Sonar Time at Target: 07/30/2004 15:12:37 Target Capture Time Local: 01/25/06 08:18:40 Target Capture Time UTC: 01/25/06 13:18:40 Target Click Position (GEO): 42° 13.50651' N 070° 31.39505' W Target Click Position (UTM83-19): N:4675893.41 E:374292.11 Acoustic Source File: I:\EFH\sw sss\raw\LINE___N.XTF, Ping:3196 Horizontal range to target: 41.08 meters to Port side Slant range to target: 41.61 meters to Port side Event Number: 0 Line Name: LINE___N	Target Description: Trawl furrows in muddy sand & gravel Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): trawl scours
	**Target: Contact0015** Sonar Time at Target: 07/30/2004 15:08:02 Target Capture Time Local: 01/25/06 08:17:26 Target Capture Time UTC: 01/25/06 13:17:26 Target Click Position (GEO): 42° 13.64788' N 070° 31.07111' W Target Click Position (UTM83-19): N:4676147.07 E:374742.35 Acoustic Source File: I:\EFH\sw sss\raw\LINE___N.XTF, Ping:756 Horizontal range to target: 50.35 meters to Stbd side Slant range to target: 51.05 meters to Stbd side Event Number: 0 Line Name: LINE___N	Target Description: Abundant trawl furrows on muddy sand Target Height =0.10 Meters Target Length: 0.00 Meters Target Shadow: 0.61 Meters Target Width: 0.81 Meters User Classification (1): trawl scours

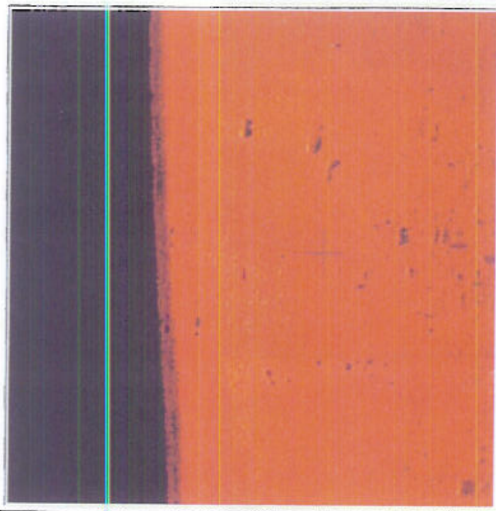
	**Target: Contact0016** Sonar Time at Target: 07/30/2004 13:44:35 Target Capture Time Local: 01/25/06 08:07:59 Target Capture Time UTC: 01/25/06 13:07:59 Target Click Position (GEO): 42° 13.72391' N 070° 30.99376' W Target Click Position (UTM83-19): N:4676285.88 E:374851.24 Acoustic Source File: I:\EFH\sw sss\raw\LINE___E.XTF, Ping:2600 Horizontal range to target: 47.02 meters to Port side Slant range to target: 48.93 meters to Port side Event Number: 0 Line Name: LINE___E	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.49 Meters User Classification (1): trawl scours
	**Target: Contact0017** Sonar Time at Target: 07/30/2004 15:06:06 Target Capture Time Local: 01/25/06 08:16:07 Target Capture Time UTC: 01/25/06 13:16:07 Target Click Position (GEO): 42° 13.63402' N 070° 30.90154' W Target Click Position (UTM83-19): N:4676117.27 E:374975.12 Acoustic Source File: I:\EFH\sw sss\raw\LINE___M.XTF, Ping:3404 Horizontal range to target: 52.77 meters to Port side Slant range to target: 53.12 meters to Port side Event Number: 0 Line Name: LINE___M	Target Description: Abundant trawl furrows on muddy sand/sandy mud Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.47 Meters User Classification (1): trawl scours
	**Target: Contact0018** Sonar Time at Target: 07/30/2004 13:46:55 Target Capture Time Local: 01/25/06 08:08:24 Target Capture Time UTC: 01/25/06 13:08:24 Target Click Position (GEO): 42° 13.77226' N 070° 30.83090' W Target Click Position (UTM83-19): N:4676371.38 E:375076.83 Acoustic Source File: I:\EFH\sw sss\raw\LINE___E.XTF, Ping:3840 Horizontal range to target: 48.55 meters to Port side Slant range to target: 50.67 meters to Port side Event Number: 0 Line Name: LINE___E	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): sand ripples

	**Target: Contact0019** Sonar Time at Target: 07/30/2004 13:50:27 Target Capture Time Local: 01/25/06 08:06:44 Target Capture Time UTC: 01/25/06 13:06:44 Target Click Position (GEO): 42° 13.79829' N 070° 30.55549' W Target Click Position (UTM83-19): N:4676412.84 E:375456.46 Acoustic Source File: I:\EFH\sw sss\raw\LINE___E.XTF, Ping:5726 Horizontal range to target: 40.33 meters to Stbd side Slant range to target: 43.26 meters to Stbd side Event Number: 0 Line Name: LINE___E	Target Description: Weathered trawl scours Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 2.23 Meters User Classification (1): trawl scours
	**Target: Contact0020** Sonar Time at Target: 07/30/2004 20:12:36 Target Capture Time Local: 01/24/06 17:04:43 Target Capture Time UTC: 01/24/06 22:04:43 Target Click Position (GEO): 42° 14.17258' N 070° 30.31495' W Target Click Position (UTM83-19): N:4677099.65 E:375799.53 Acoustic Source File: I:\EFH\sw sss\raw\wreck4b.xtf, Ping:1553 Horizontal range to target: 23.84 meters to Port side Slant range to target: 31.25 meters to Port side Event Number: 0 Line Name: wreck4b	No user entries.
	**Target: Contact0021** Sonar Time at Target: 07/30/2004 20:12:43 Target Capture Time Local: 01/25/06 08:53:41 Target Capture Time UTC: 01/25/06 13:53:41 Target Click Position (GEO): 42° 14.21661' N 070° 30.28483' W Target Click Position (UTM83-19): N:4677180.40 E:375842.39 Acoustic Source File: I:\EFH\sw sss\raw\wreck4b.xtf, Ping:1620 Horizontal range to target: 67.46 meters to Stbd side Slant range to target: 71.41 meters to Stbd side Event Number: 0 Line Name: wreck4b	Target Description: Debris associated with wreckage Target Height =0.38 Meters Target Length: 10.56 Meters Target Shadow: 1.19 Meters Target Width: 5.50 Meters User Classification (1): Man Made Debris

	**Target: Contact0022** Sonar Time at Target: 07/30/2004 19:43:28 Target Capture Time Local: 01/24/06 18:11:11 Target Capture Time UTC: 01/24/06 23:11:11 Target Click Position (GEO): 42° 14.12569' N 070° 30.22743' W Target Click Position (UTM83-19): N:4677010.75 E:375918.36 Acoustic Source File: I:\EFH\sw sss\raw\wreck-5.xtf, Ping:1993 Horizontal range to target: 57.58 meters to Stbd side Slant range to target: 61.68 meters to Stbd side Event Number: 0 Line Name: wreck-5	Target Description: Bronze wreck Target Height =5.56 Meters Target Length: 51.08 Meters Target Shadow: 18.68 Meters Target Width: 17.84 Meters User Classification (1): wreckage
	**Target: Contact0023** Sonar Time at Target: 07/30/2004 20:02:39 Target Capture Time Local: 01/25/06 08:31:33 Target Capture Time UTC: 01/25/06 13:31:33 Target Click Position (GEO): 42° 14.09648' N 070° 30.22399' W Target Click Position (UTM83-19): N:4676956.62 E:375922.13 Acoustic Source File: I:\EFH\sw sss\raw\wreck4a___A.xtf, Ping:244 Horizontal range to target: 47.03 meters to Stbd side Slant range to target: 50.33 meters to Stbd side Event Number: 0 Line Name: wreck4a___A	Target Description: Bronze wreck. Image of bow and cross-members Target Height >=4.80 Meters Target Length: 109.87 Meters Target Shadow: 18.37 Meters Target Width: 16.72 Meters User Classification (1): wreckage
	**Target: Contact0024** Sonar Time at Target: 07/30/2004 19:43:05 Target Capture Time Local: 01/24/06 18:12:00 Target Capture Time UTC: 01/24/06 23:12:00 Target Click Position (GEO): 42° 14.18158' N 070° 30.21174' W Target Click Position (UTM83-19): N:4677113.80 E:375941.75 Acoustic Source File: I:\EFH\sw sss\raw\wreck-5.xtf, Ping:1789 Horizontal range to target: 20.66 meters to Port side Slant range to target: 28.71 meters to Port side Event Number: 0 Line Name: wreck-5	Target Description: likely anchor associated with Bronze wreck Target Height =3.17 Meters Target Length: 6.28 Meters Target Shadow: 4.76 Meters Target Width: 1.26 Meters User Classification (1): wreckage

	**Target: Contact0025** Sonar Time at Target: 07/30/2004 13:56:23 Target Capture Time Local: 01/25/06 08:09:20 Target Capture Time UTC: 01/25/06 13:09:20 Target Click Position (GEO): 42° 13.95627' N 070° 30.17060' W Target Click Position (UTM83-19): N:4676695.84 E:375990.98 Acoustic Source File: I:\EFH\sw sss\raw\LINE___F.XTF, Ping:1455 Horizontal range to target: 49.00 meters to Port side Slant range to target: 51.20 meters to Port side Event Number: 0 Line Name: LINE___F	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): gravel
	**Target: Contact0026** Sonar Time at Target: 07/30/2004 14:52:54 Target Capture Time Local: 01/25/06 08:14:55 Target Capture Time UTC: 01/25/06 13:14:55 Target Click Position (GEO): 42° 13.98013' N 070° 29.87964' W Target Click Position (UTM83-19): N:4676732.95 E:376391.92 Acoustic Source File: I:\EFH\sw sss\raw\LINE___L.XTF, Ping:3801 Horizontal range to target: 54.86 meters to Stbd side Slant range to target: 56.06 meters to Stbd side Event Number: 0 Line Name: LINE___L	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.44 Meters User Classification (1): trawl scours
	**Target: Contact0027** Sonar Time at Target: 07/30/2004 14:49:01 Target Capture Time Local: 01/25/06 08:14:31 Target Capture Time UTC: 01/25/06 13:14:31 Target Click Position (GEO): 42° 14.06036' N 070° 29.55804' W Target Click Position (UTM83-19): N:4676873.67 E:376836.81 Acoustic Source File: I:\EFH\sw sss\raw\LINE___L.XTF, Ping:1726 Horizontal range to target: 52.28 meters to Stbd side Slant range to target: 54.26 meters to Stbd side Event Number: 0 Line Name: LINE___L	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): trawl scours

	**Target: Contact0028** Sonar Time at Target: 07/30/2004 19:16:57 Target Capture Time Local: 01/24/06 18:16:16 Target Capture Time UTC: 01/24/06 23:16:16 Target Click Position (GEO): 42° 14.00084' N 070° 29.13418' W Target Click Position (UTM83-19): N:4676753.33 E:377417.81 Acoustic Source File: I:\EFH\sw sss\raw\line10___A.xtf, Ping:351 Horizontal range to target: 45.49 meters to Stbd side Slant range to target: 48.68 meters to Stbd side Event Number: 0 Line Name: line10___A	Target Description: N/A Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): gravel
	**Target: Contact0029** Sonar Time at Target: 07/30/2004 14:20:47 Target Capture Time Local: 01/25/06 08:11:30 Target Capture Time UTC: 01/25/06 13:11:30 Target Click Position (GEO): 42° 14.37486' N 070° 28.64386' W Target Click Position (UTM83-19): N:4677433.78 E:378104.14 Acoustic Source File: I:\EFH\sw sss\raw\LINE___I.XTF, Ping:3033 Horizontal range to target: 39.51 meters to Port side Slant range to target: 45.03 meters to Port side Event Number: 0 Line Name: LINE___I	Target Description: N/A Target Height =0.00 Meters Target Length: 41.08 Meters Target Shadow: 0.00 Meters Target Width: 31.43 Meters User Classification (1): gravel ridges
	**Target: Contact0030** Sonar Time at Target: 07/30/2004 19:04:40 Target Capture Time Local: 01/24/06 18:15:09 Target Capture Time UTC: 01/24/06 23:15:09 Target Click Position (GEO): 42° 14.19800' N 070° 28.40608' W Target Click Position (UTM83-19): N:4677100.81 E:378425.46 Acoustic Source File: I:\EFH\sw sss\raw\line10.xtf, Ping:1239 Horizontal range to target: 14.78 meters to Stbd side Slant range to target: 16.54 meters to Stbd side Event Number: 0 Line Name: line10	Target Description: N/A Target Height =2.21 Meters Target Length: 4.98 Meters Target Shadow: 6.73 Meters Target Width: 1.17 Meters User Classification (1): floating debris

	**Target: Contact0031** Sonar Time at Target: 07/30/2004 14:27:51 Target Capture Time Local: 01/25/06 08:12:35 Target Capture Time UTC: 01/25/06 13:12:35 Target Click Position (GEO): 42° 14.43705' N 070° 28.18528' W Target Click Position (UTM83-19): N:4677537.96 E:378736.74 Acoustic Source File: I:\EFH\sw sss\raw\LINE___I.XTF, Ping:6800 Horizontal range to target: 54.80 meters to Stbd side Slant range to target: 60.82 meters to Stbd side Event Number: 0 Line Name: LINE___I	Target Description: Sandy gravel bottom with abundant cobbles and boulders Target Height =0.00 Meters Target Length: 0.00 Meters Target Shadow: 0.00 Meters Target Width: 0.00 Meters User Classification (1): cobble

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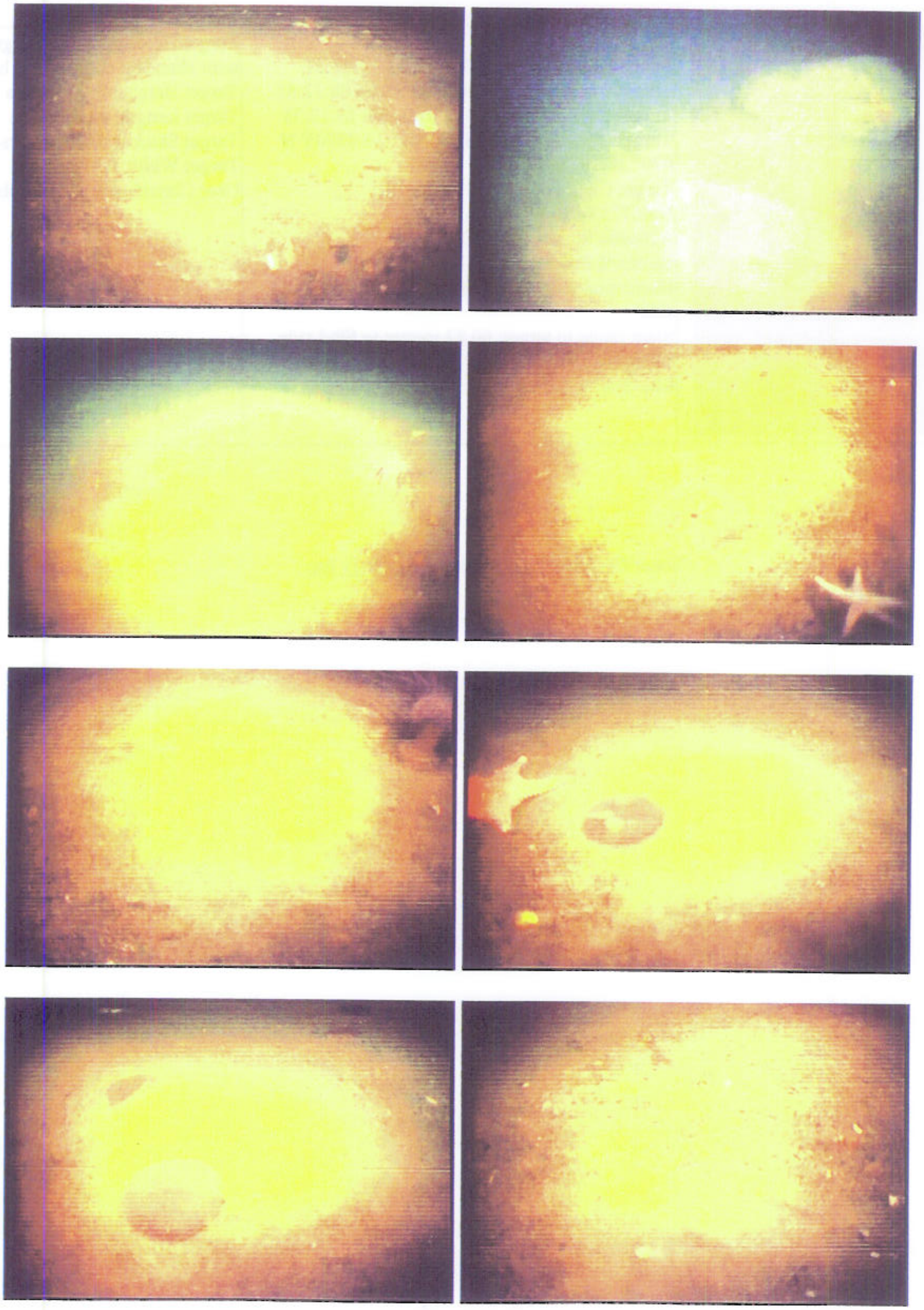
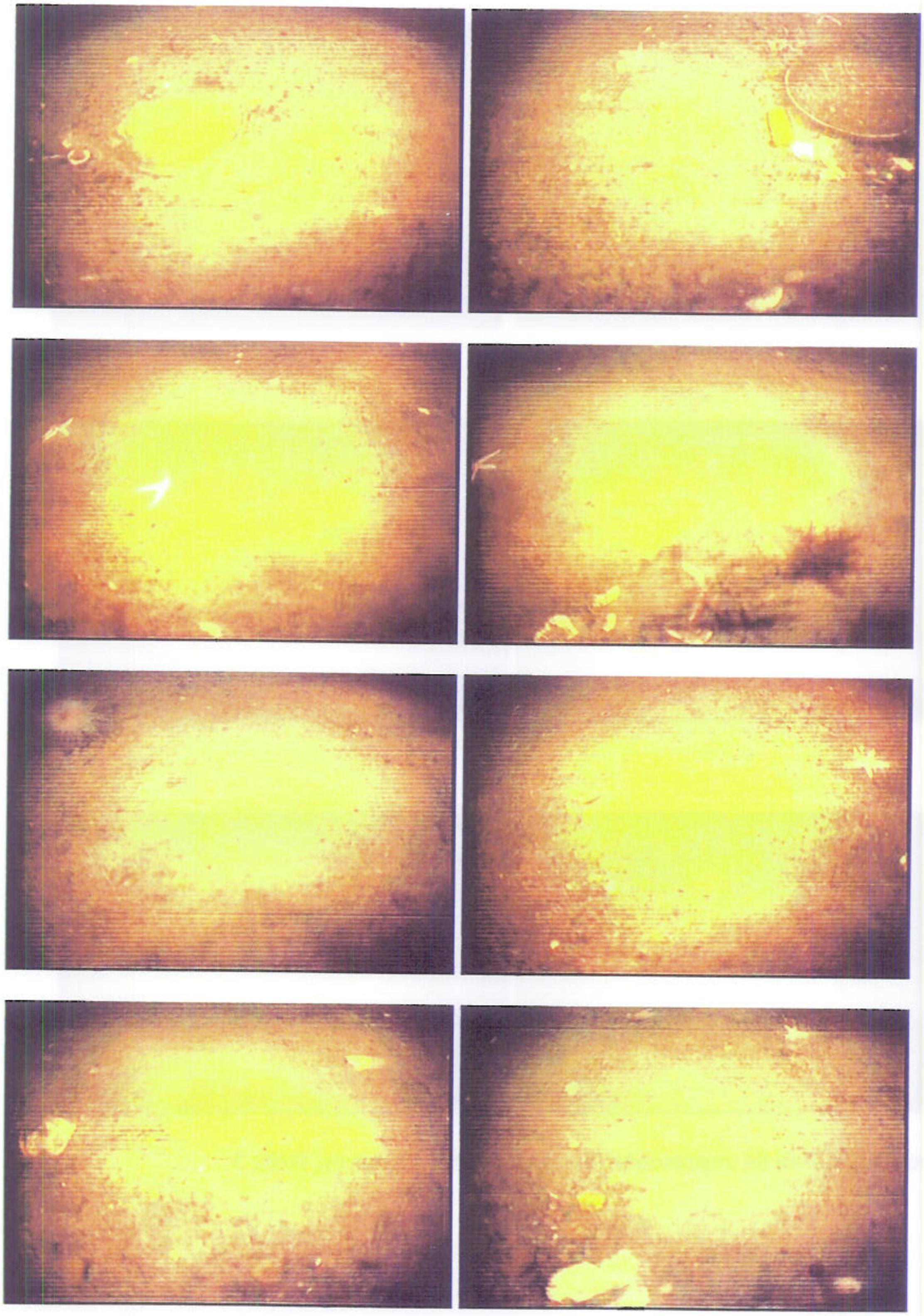
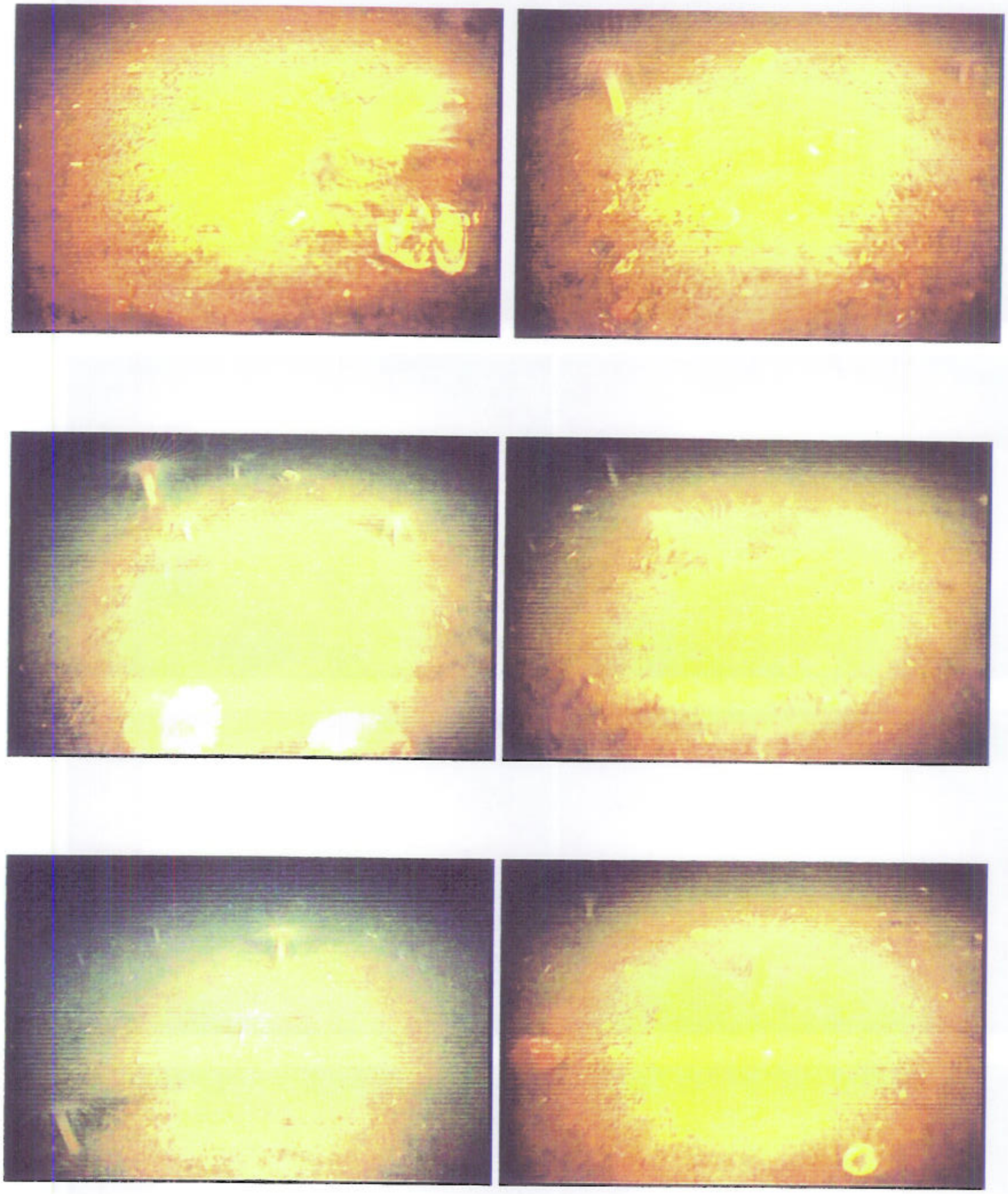


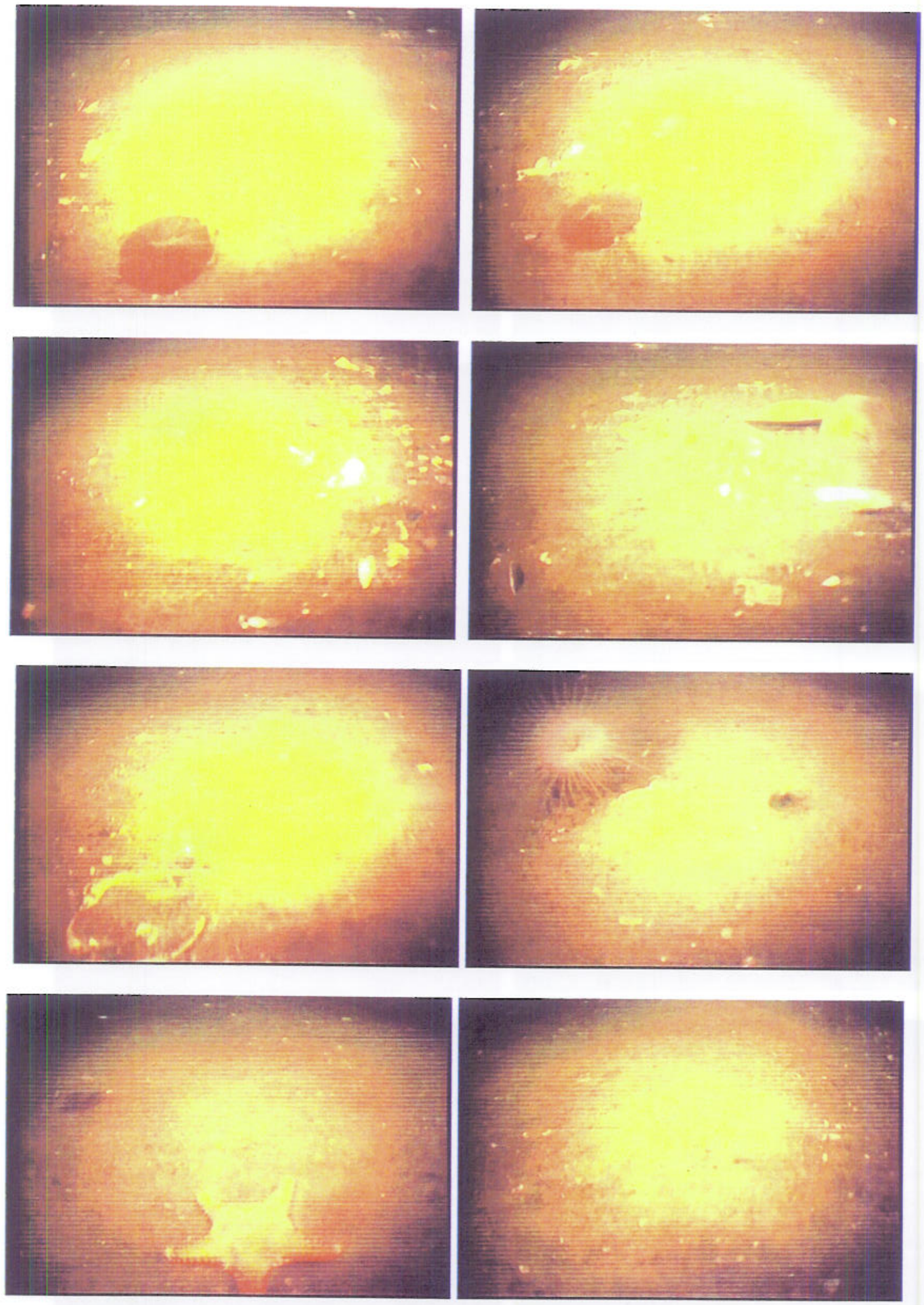
Pigeon Hills, Fall 04 representative video screen captures, Drift 1



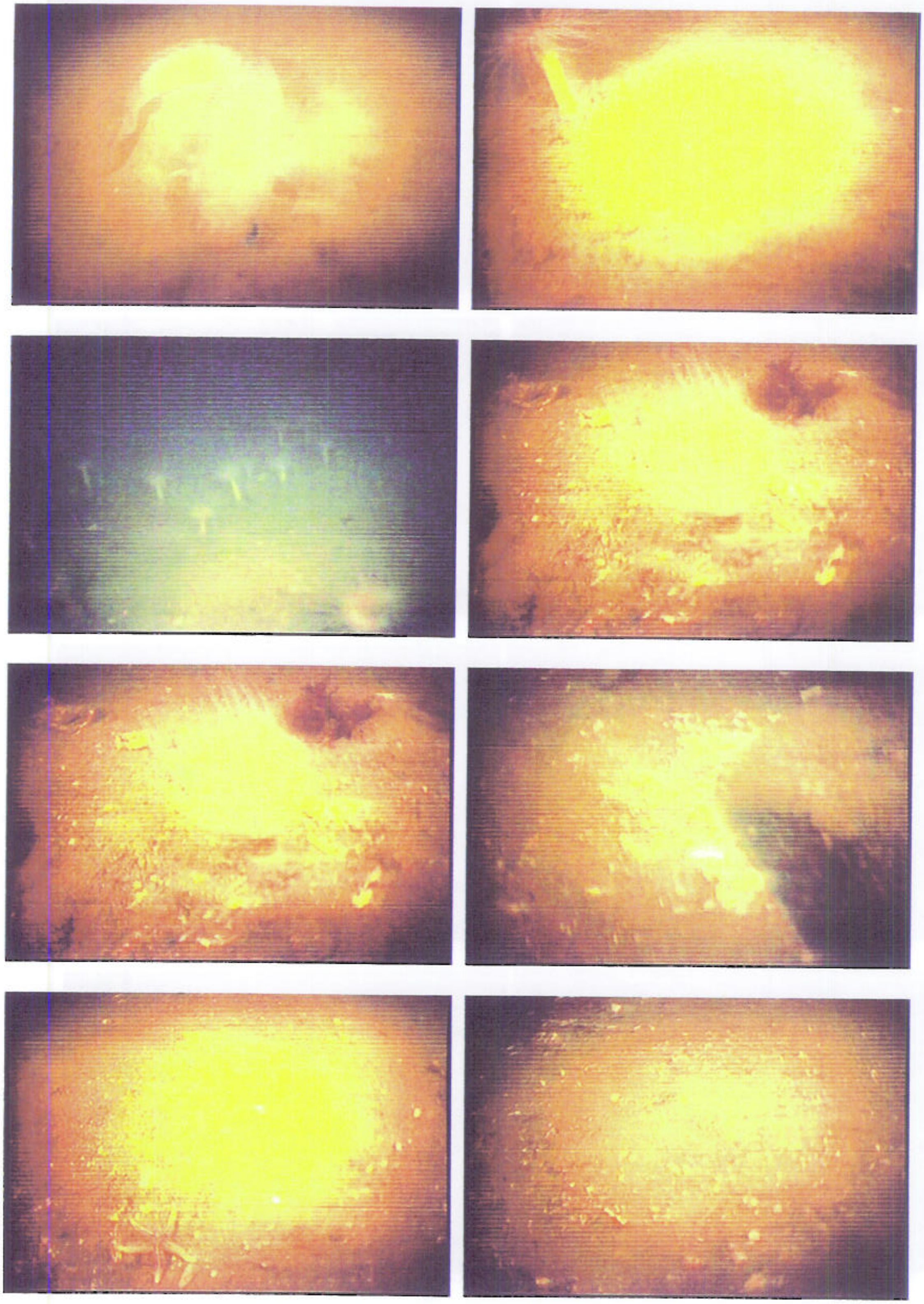
Pigeon Hills, Fall 04 representative video screen captures, Drift 2



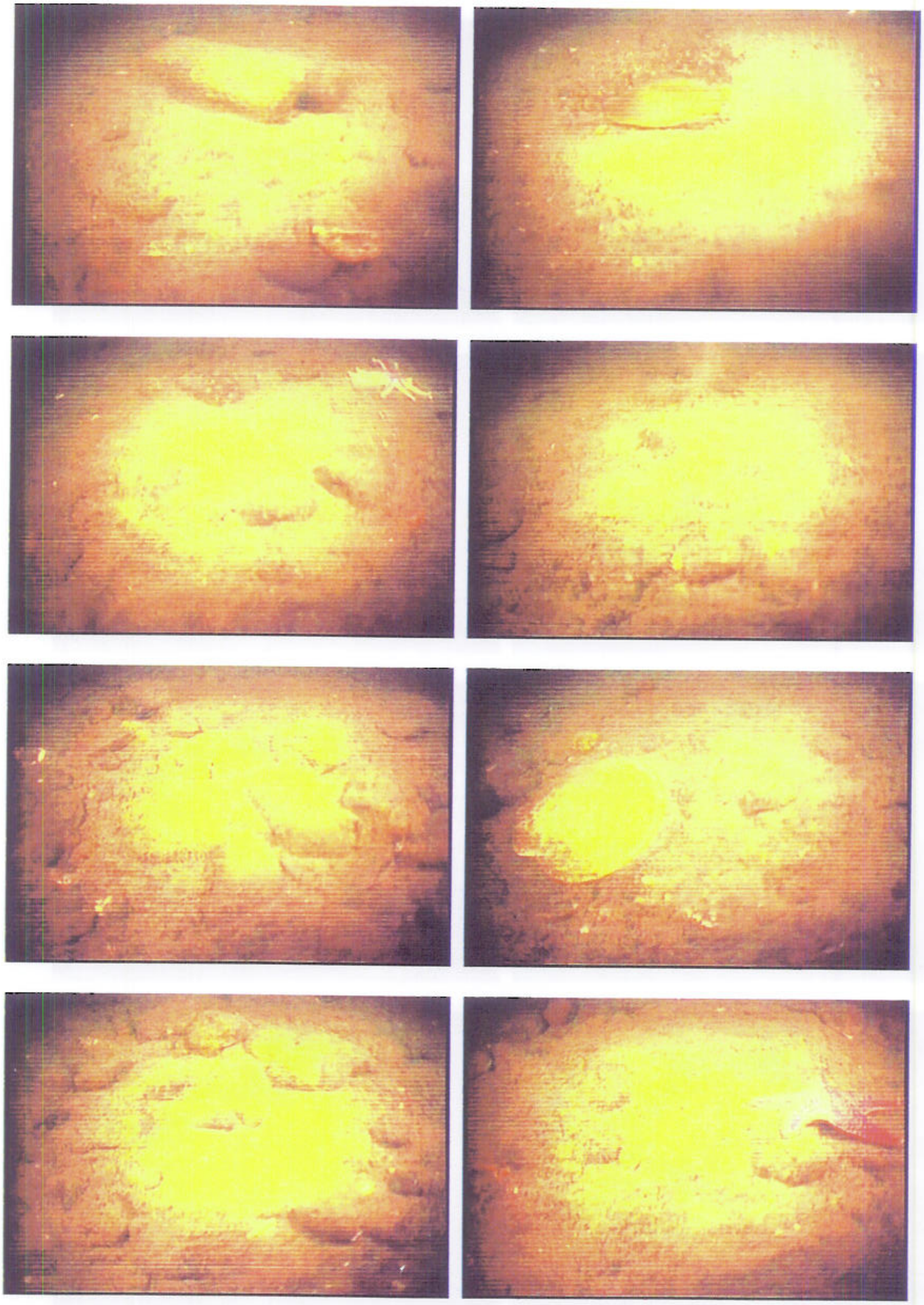
Pigeon Hills, Fall 04 representative video screen captures, Drift 3



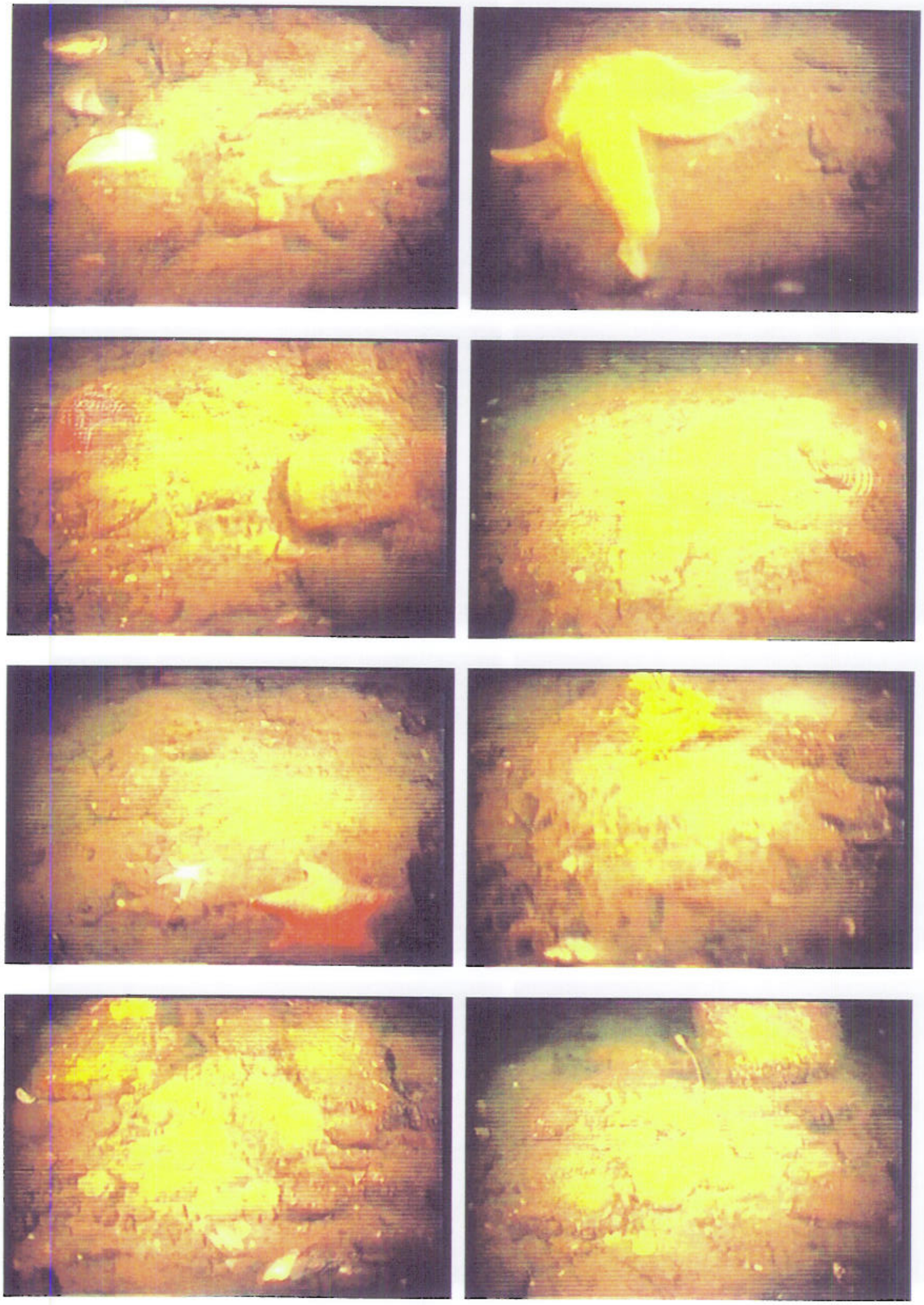
Pigeon Hills, Fall 04 representative video screen captures, Drift 4



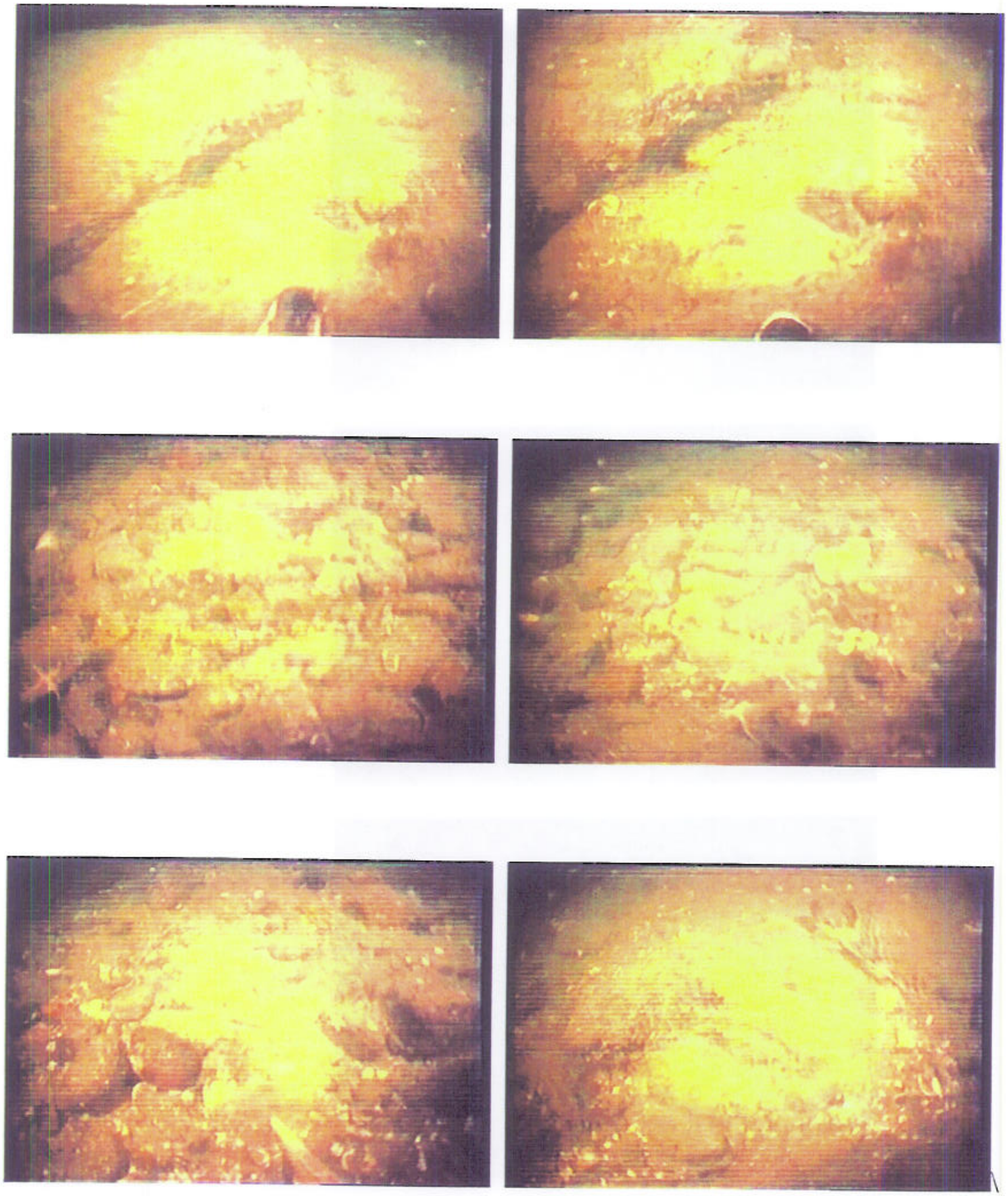
Pigeon Hills, Fall 04 representative video screen captures, Drift 5



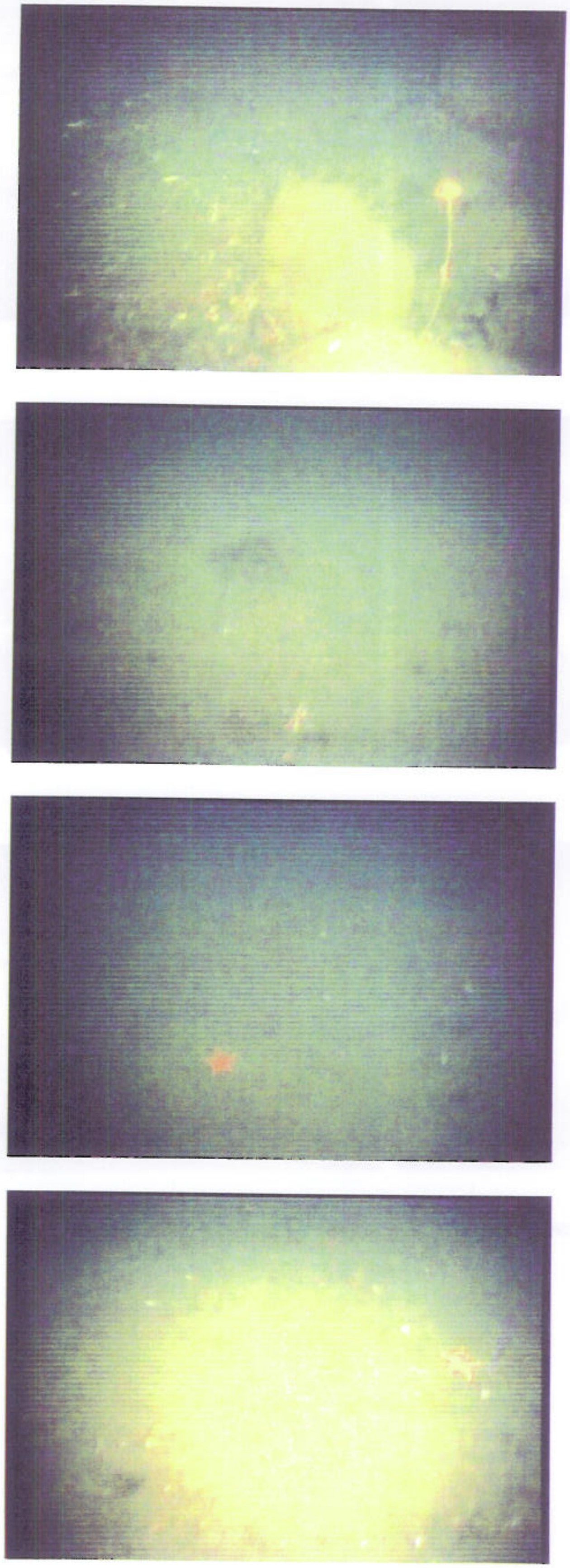
Pigeon Hills, Fall 04 representative video screen captures, Drift 6



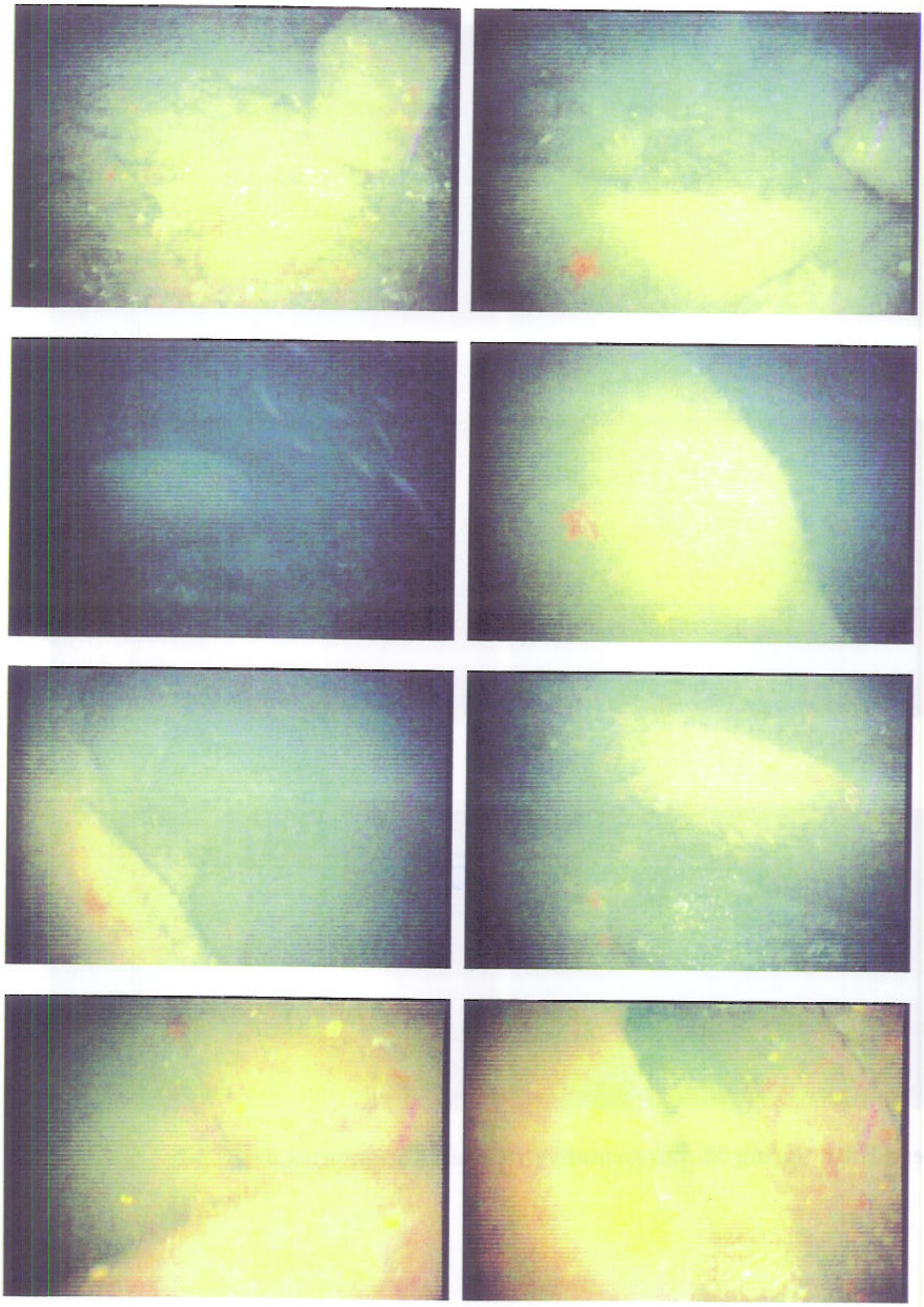
Pigeon Hills, Fall 04 representative video screen captures, Drift 7



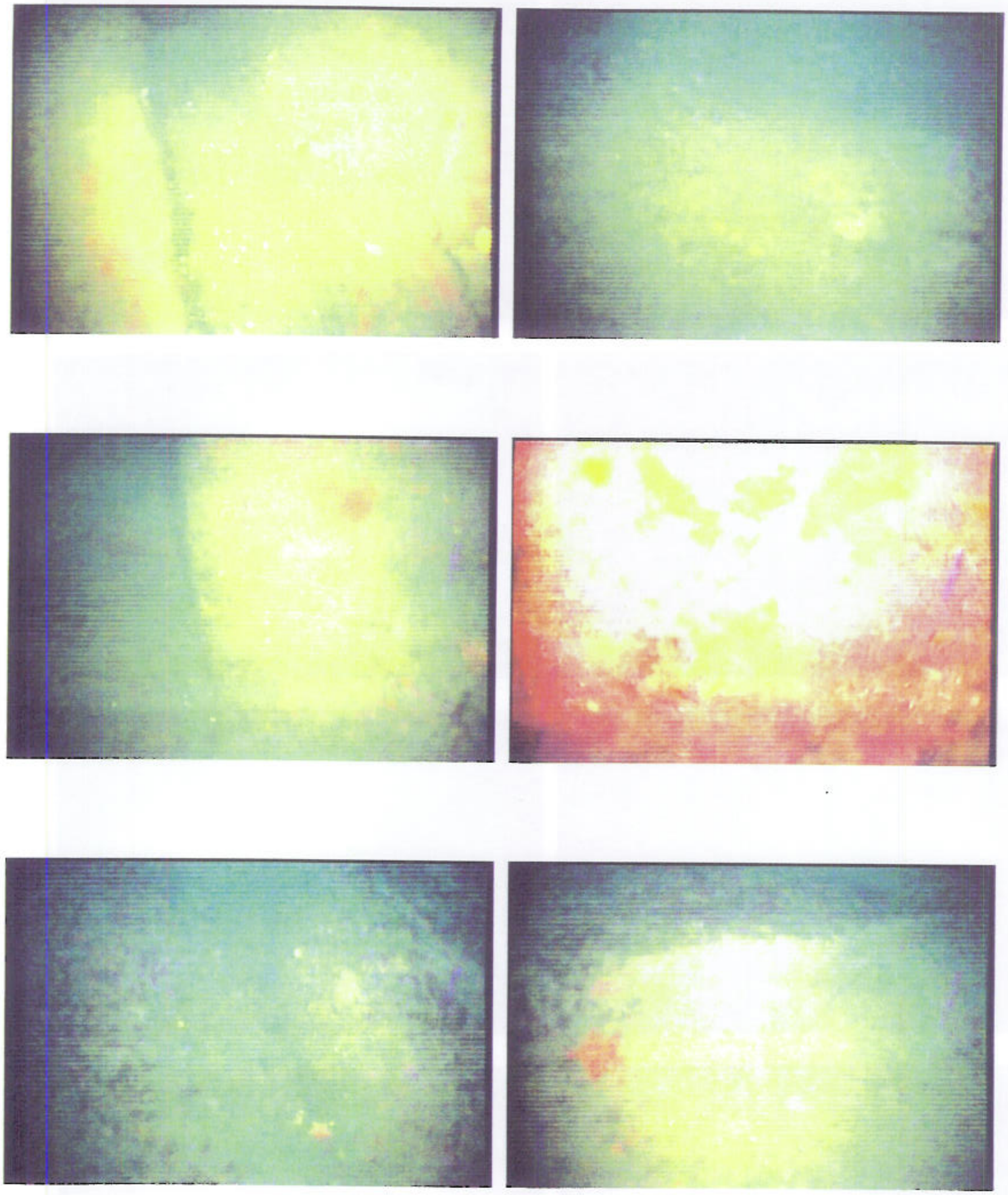
Pigeon Hills, Fall 04 representative video screen captures, Drift 8



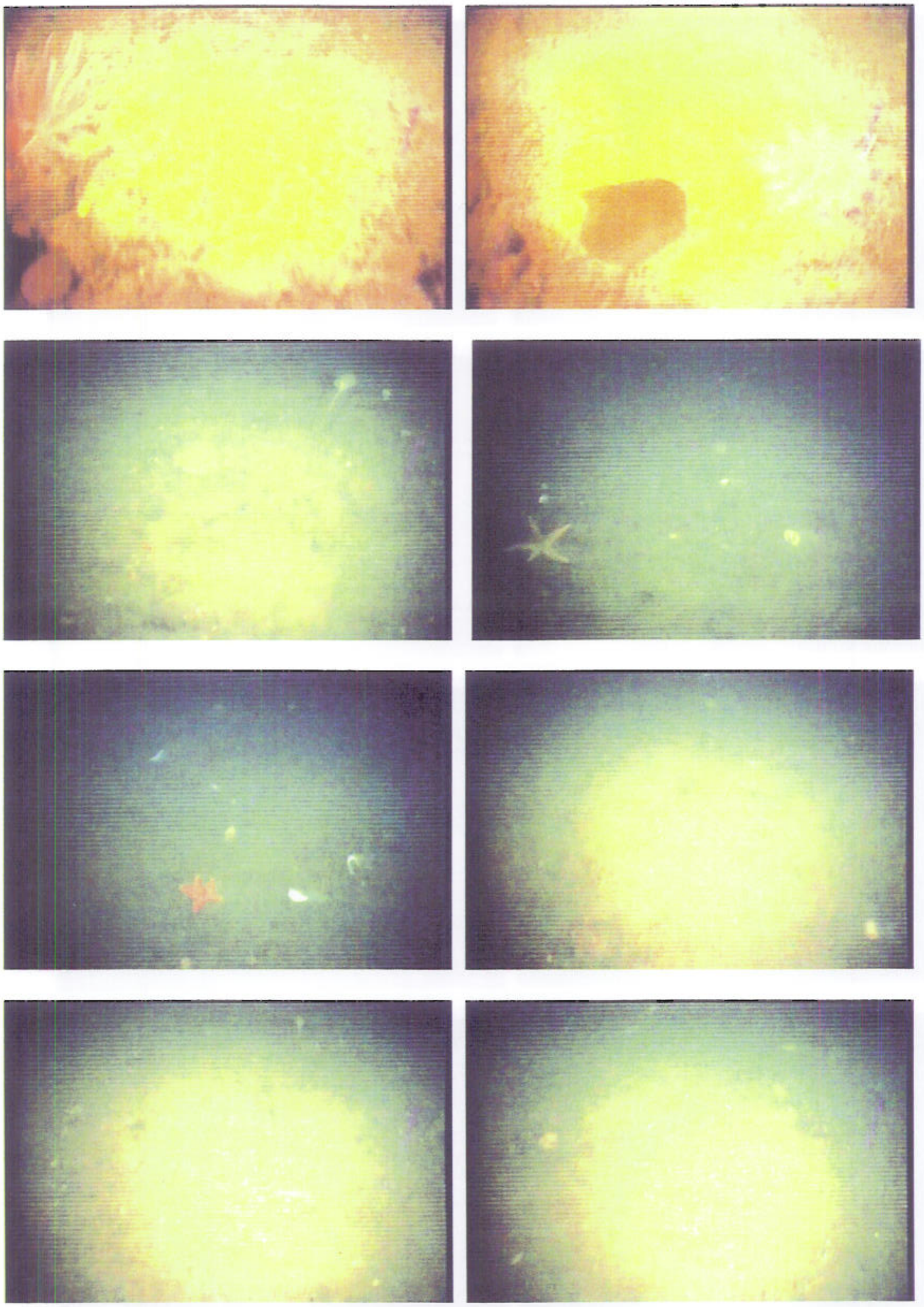
Pigeon Hills, Spring 05 representative video screen captures, Drift 1



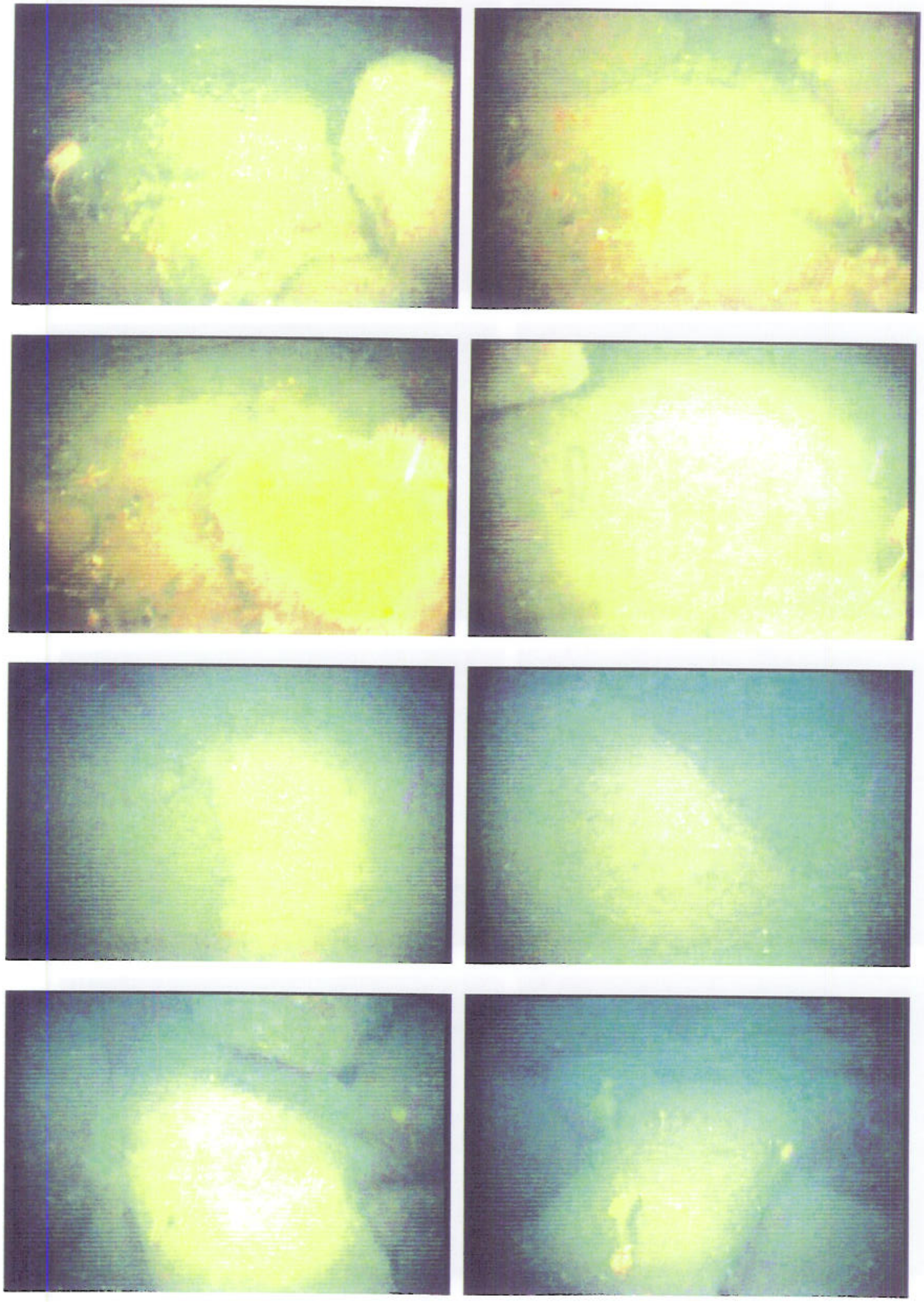
Pigeon Hills, Spring 05 representative video screen captures, Drift 2-1



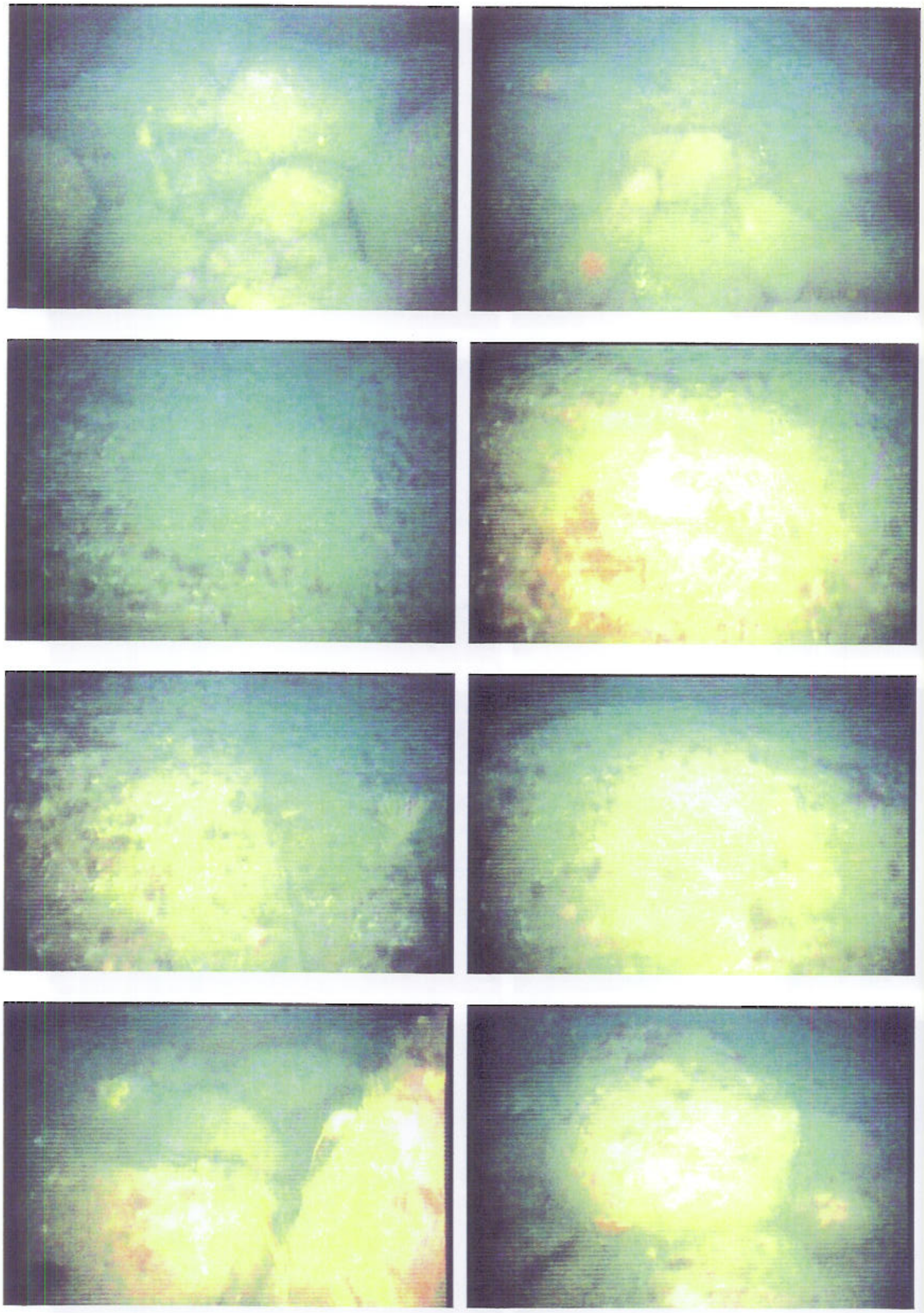
Pigeon Hills, Spring 05 representative video screen captures, Drift 2-2



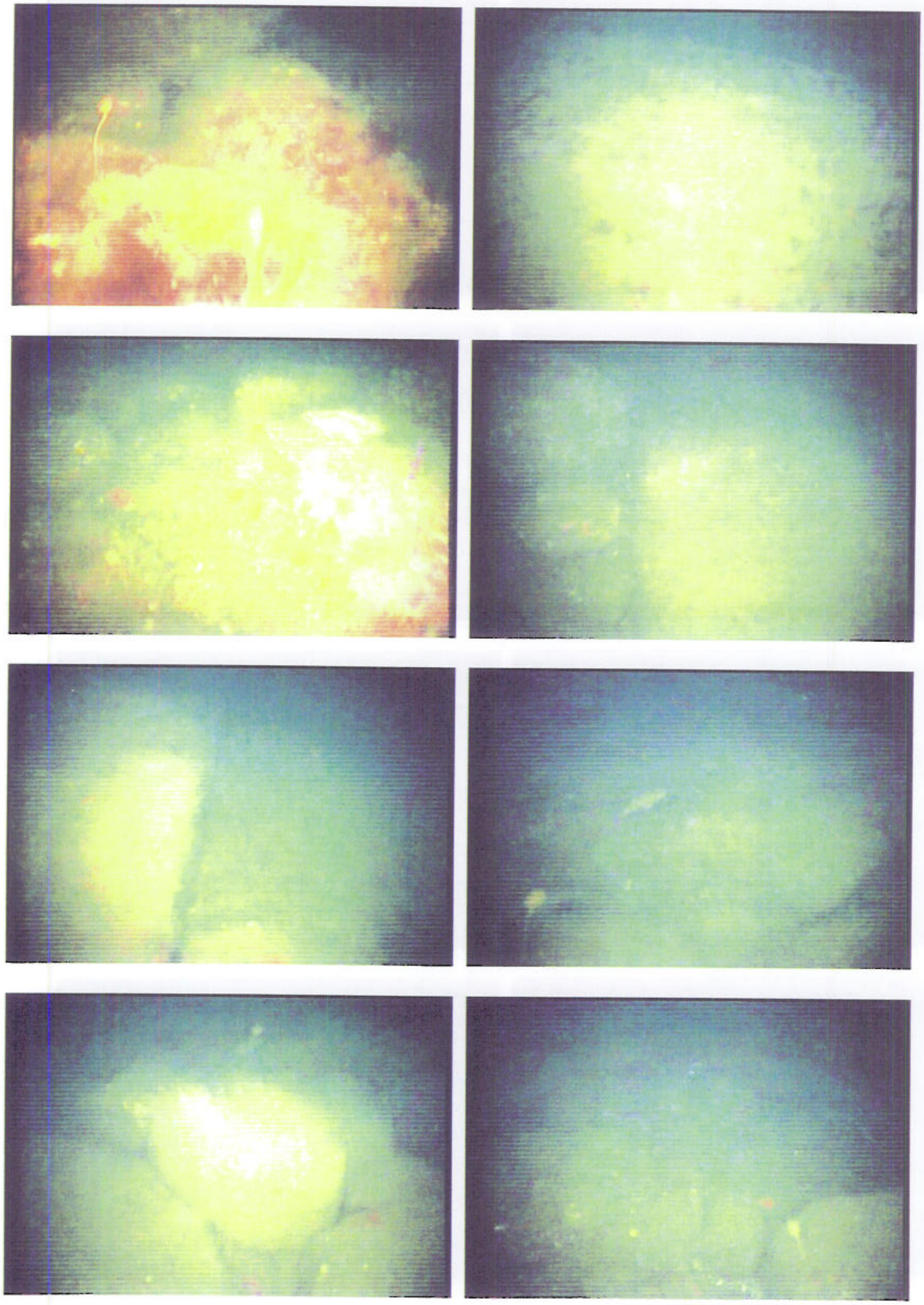
Pigeon Hills, Spring 05 representative video screen captures, Drift 3



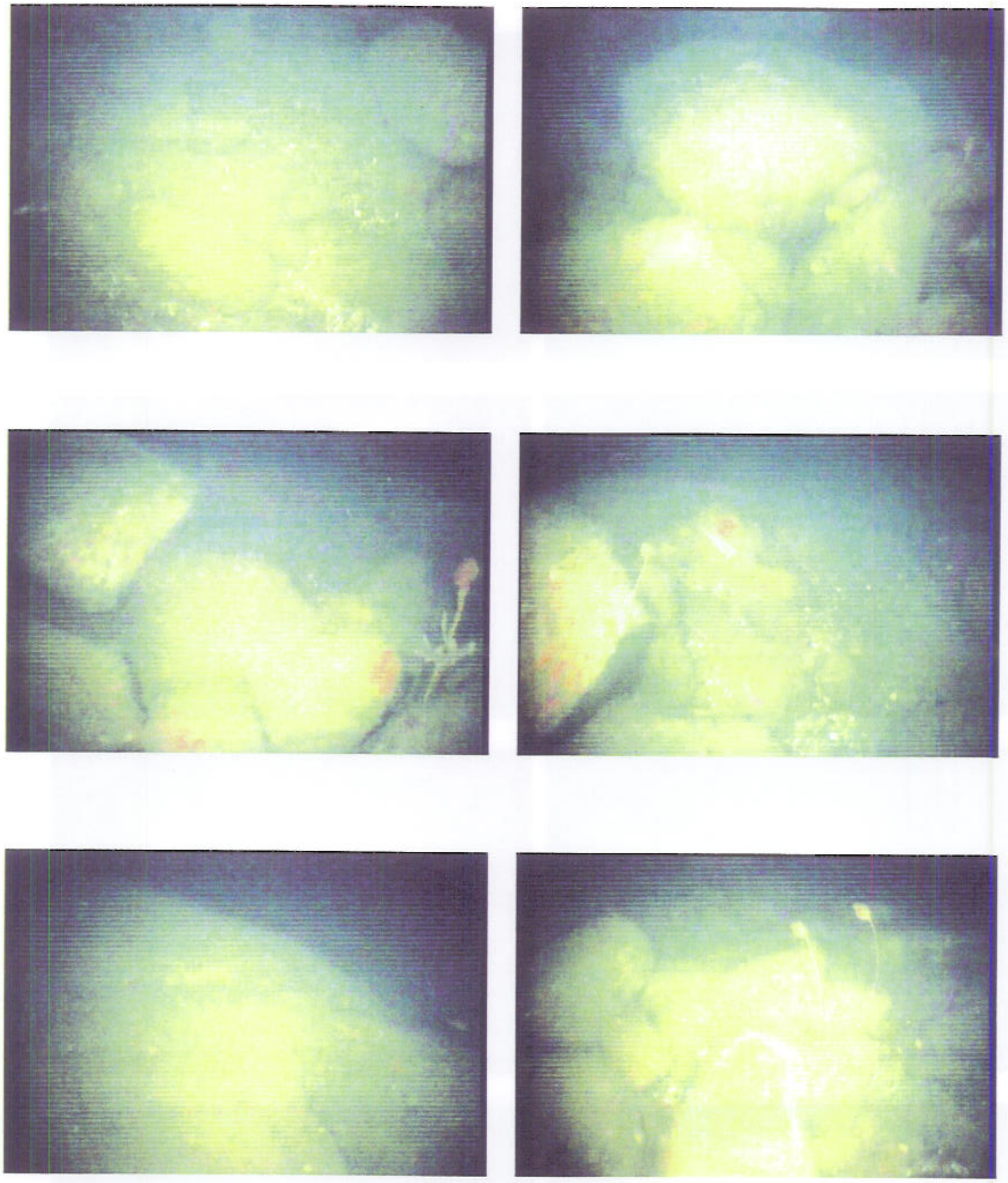
Pigeon Hills, Spring 05 representative video screen captures, Drift 4-1



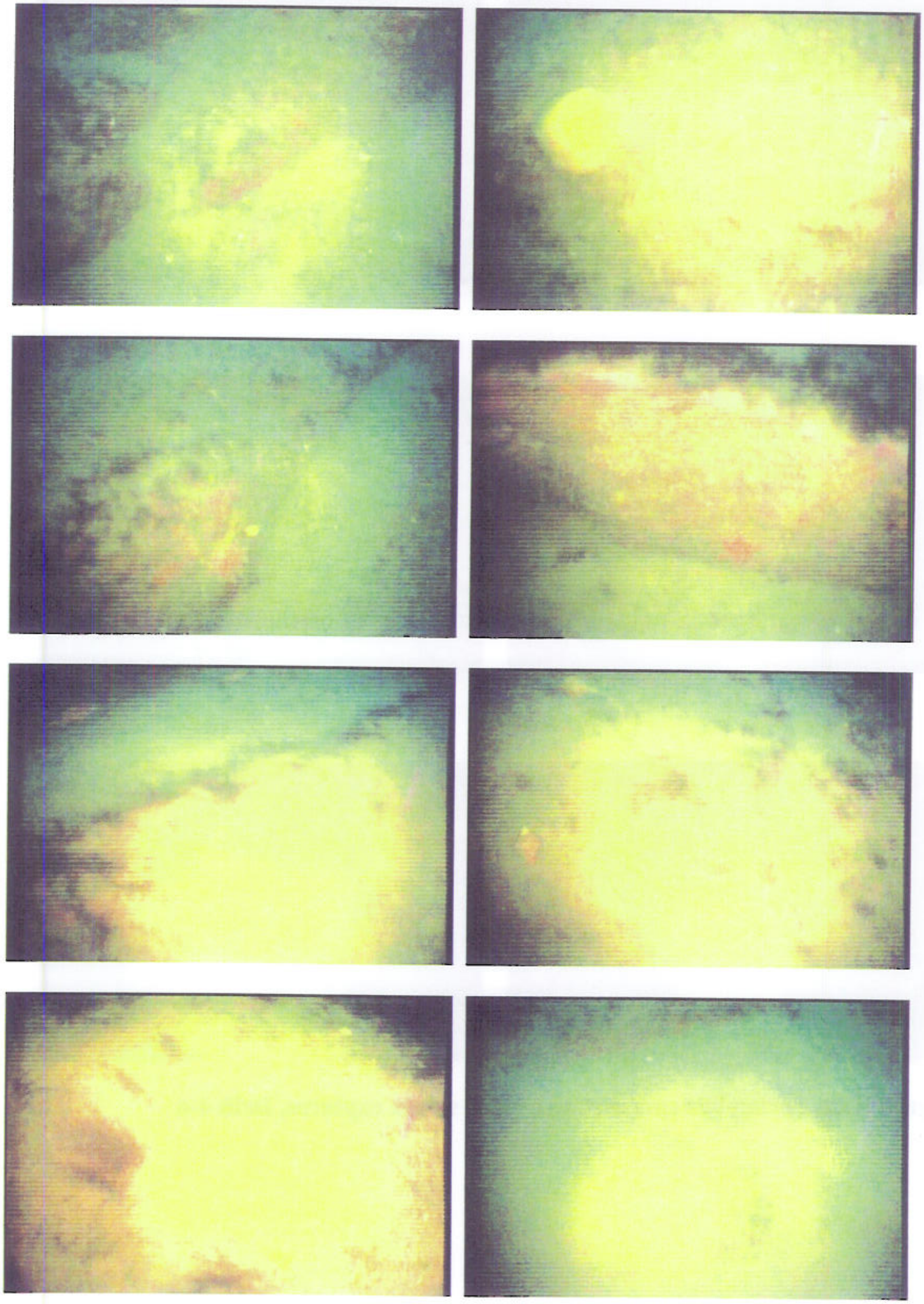
Pigeon Hills, Spring 05 representative video screen captures, Drift 4-2



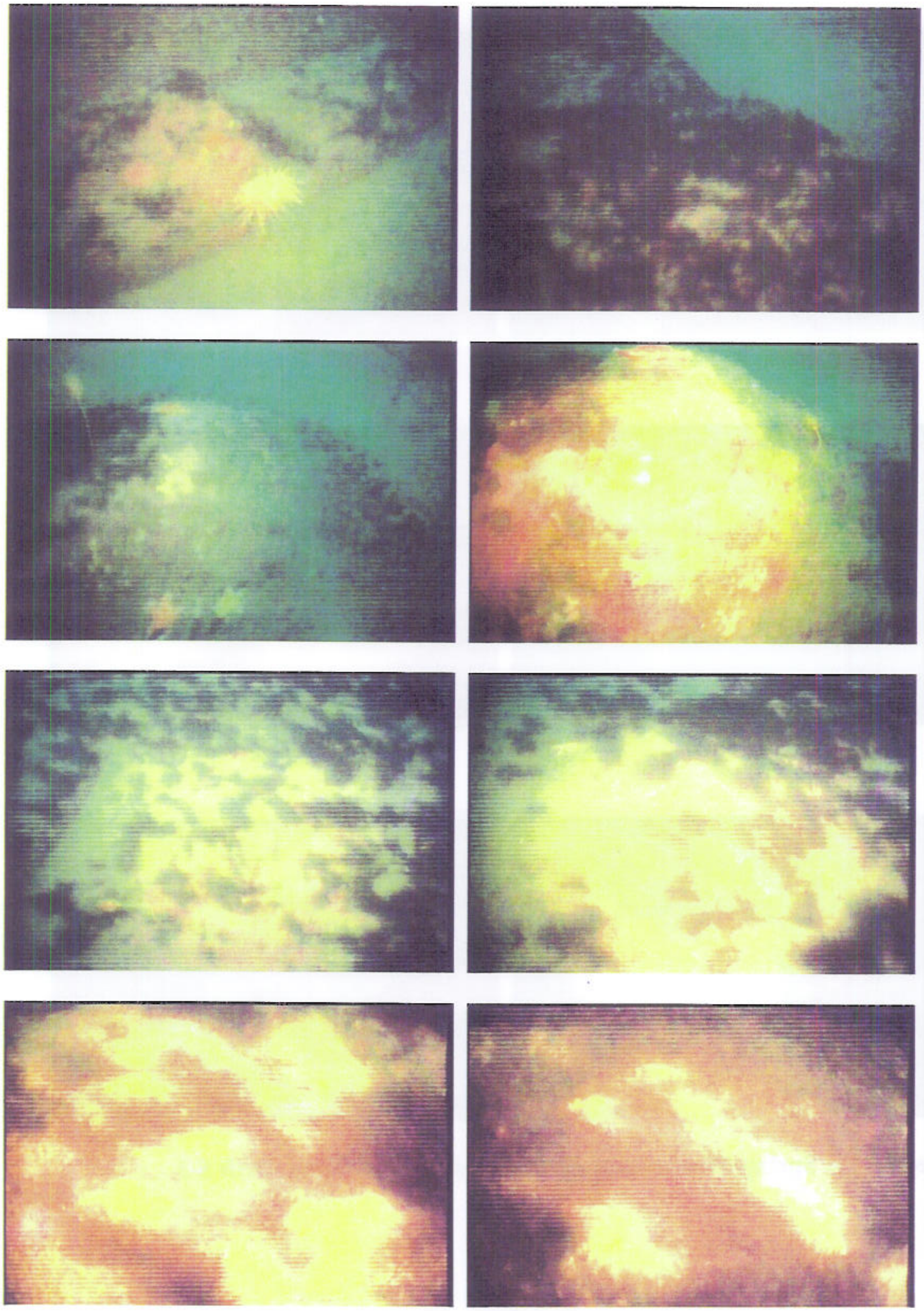
Pigeon Hills, Spring 05 representative video screen captures, Drift 4-3



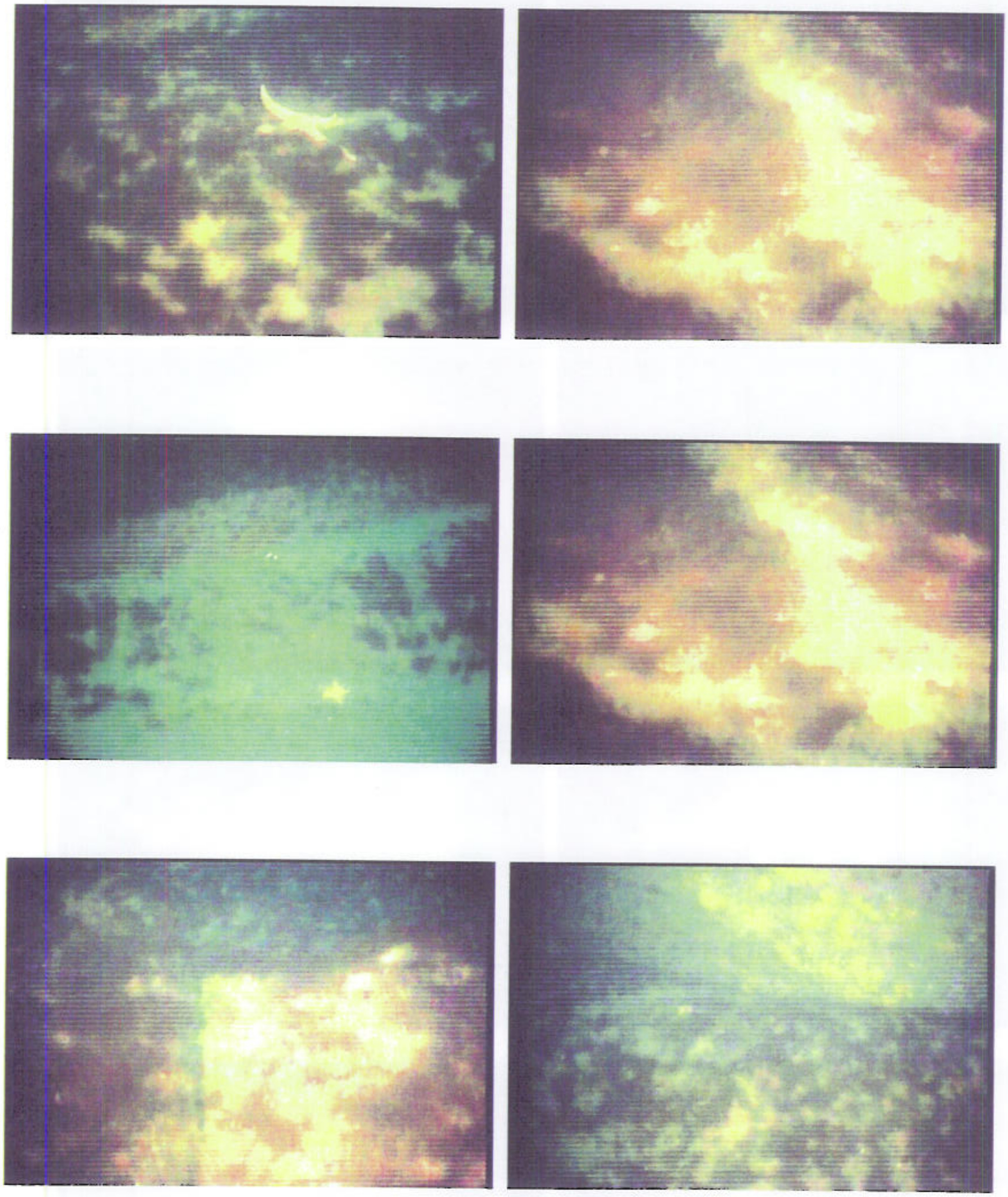
Pigeon Hills, Spring 05 representative video screen captures, Drift 4-4



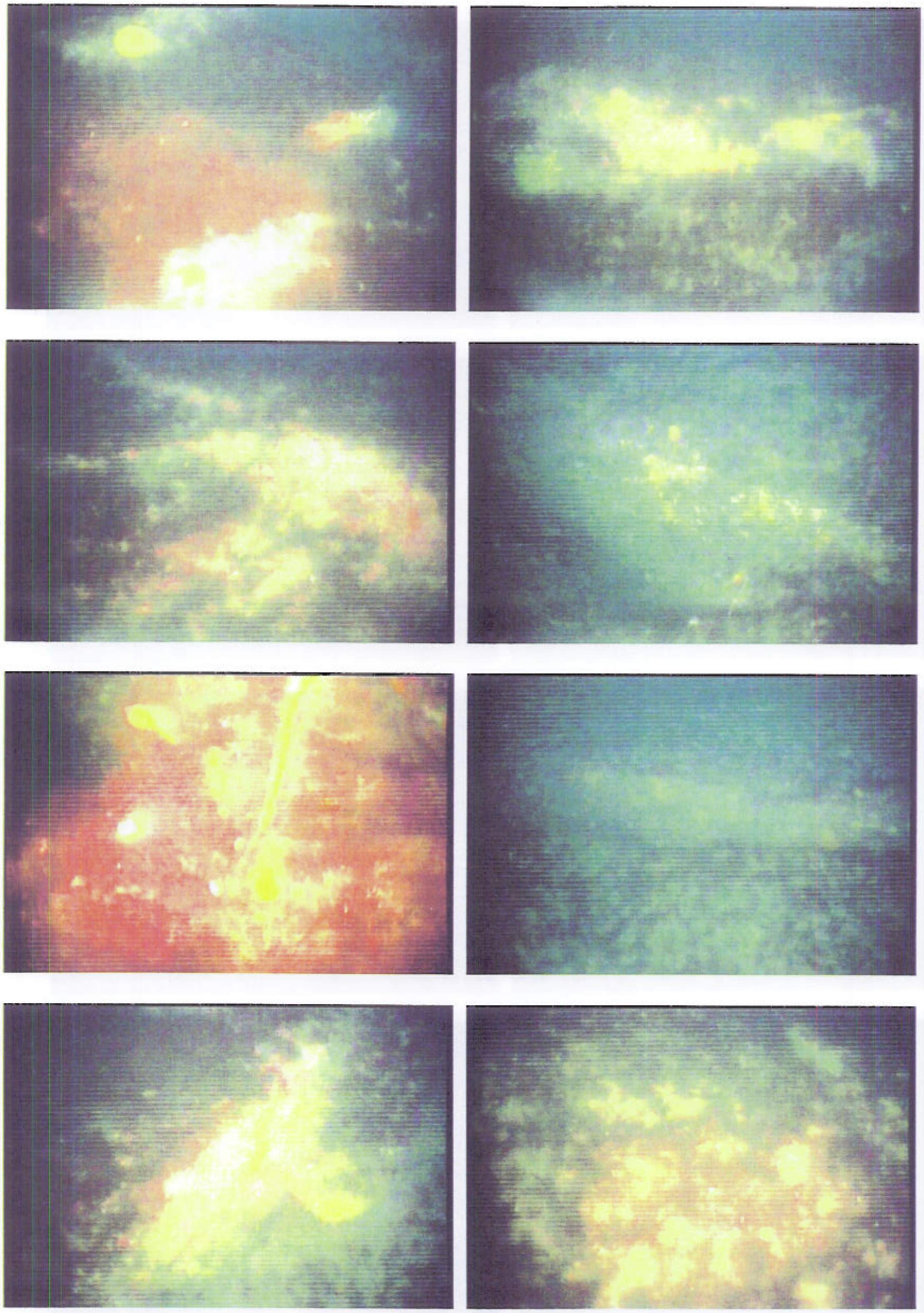
Pigeon Hills, Spring 05 representative video screen captures, Drift 5-1



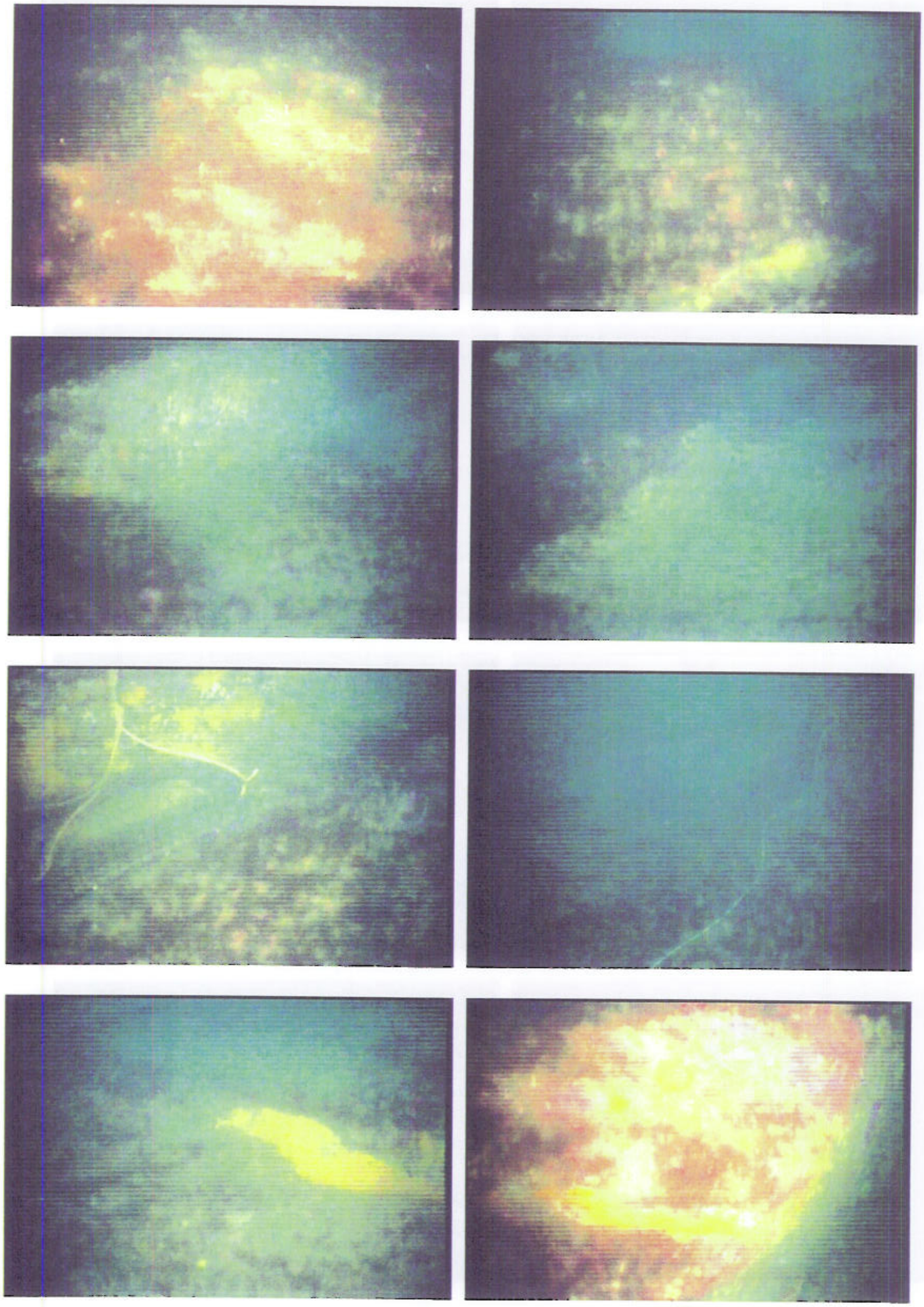
Pigeon Hills, Spring 05 representative video screen captures, Drift 5-2



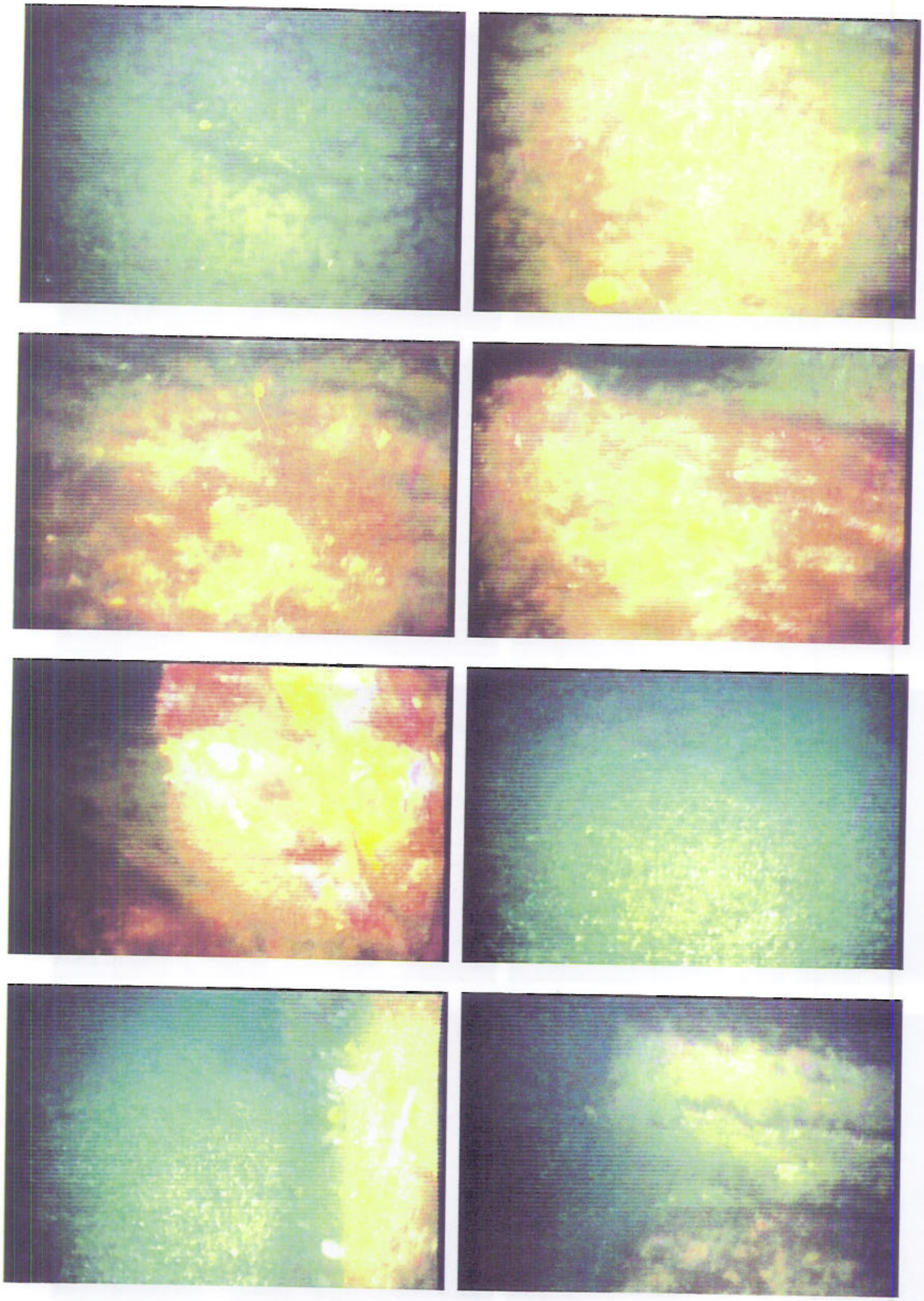
Pigeon Hills, Spring 05 representative video screen captures, Drift 5-3



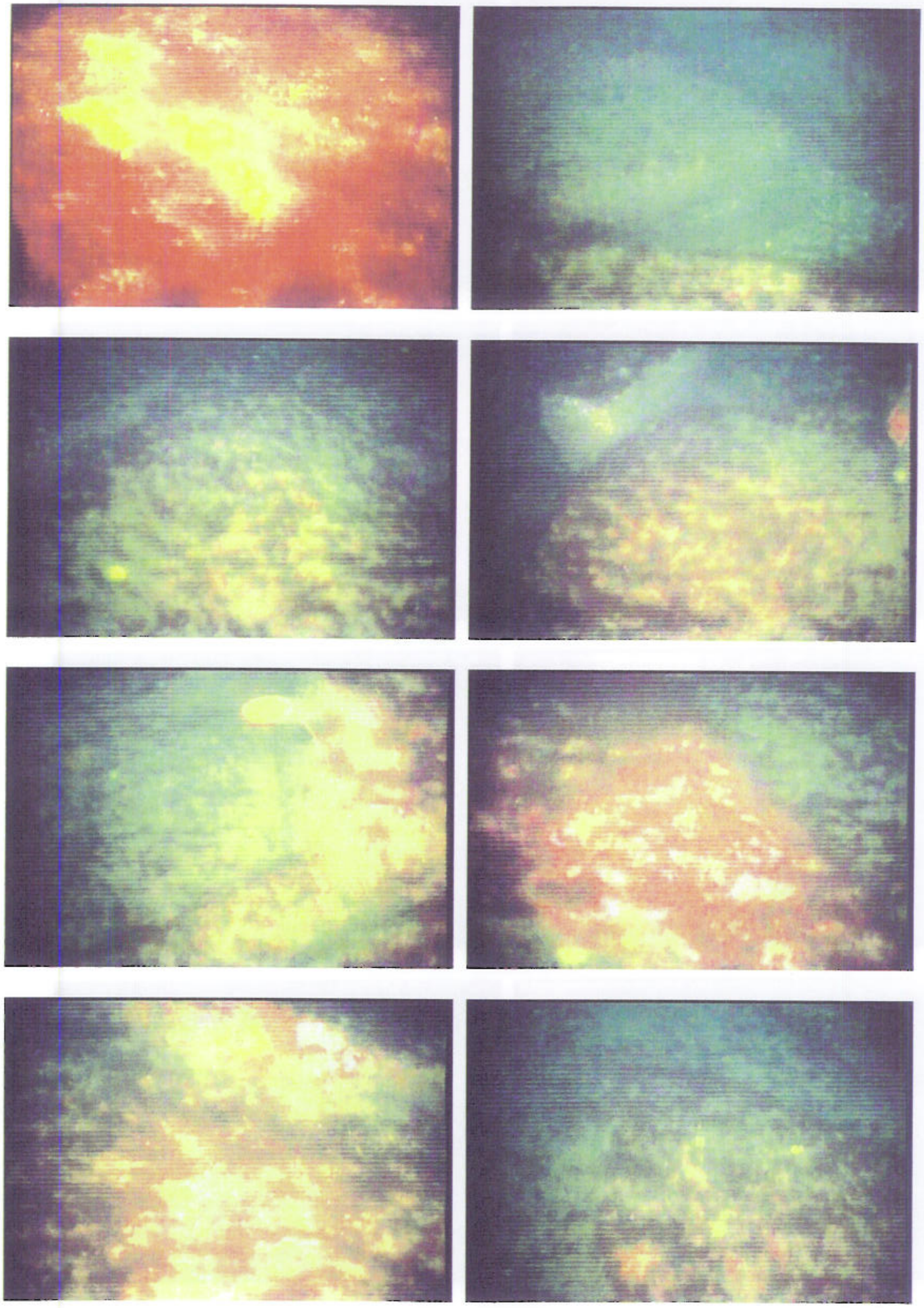
Pigeon Hills, Spring 05 representative video screen captures, Drift 6-1



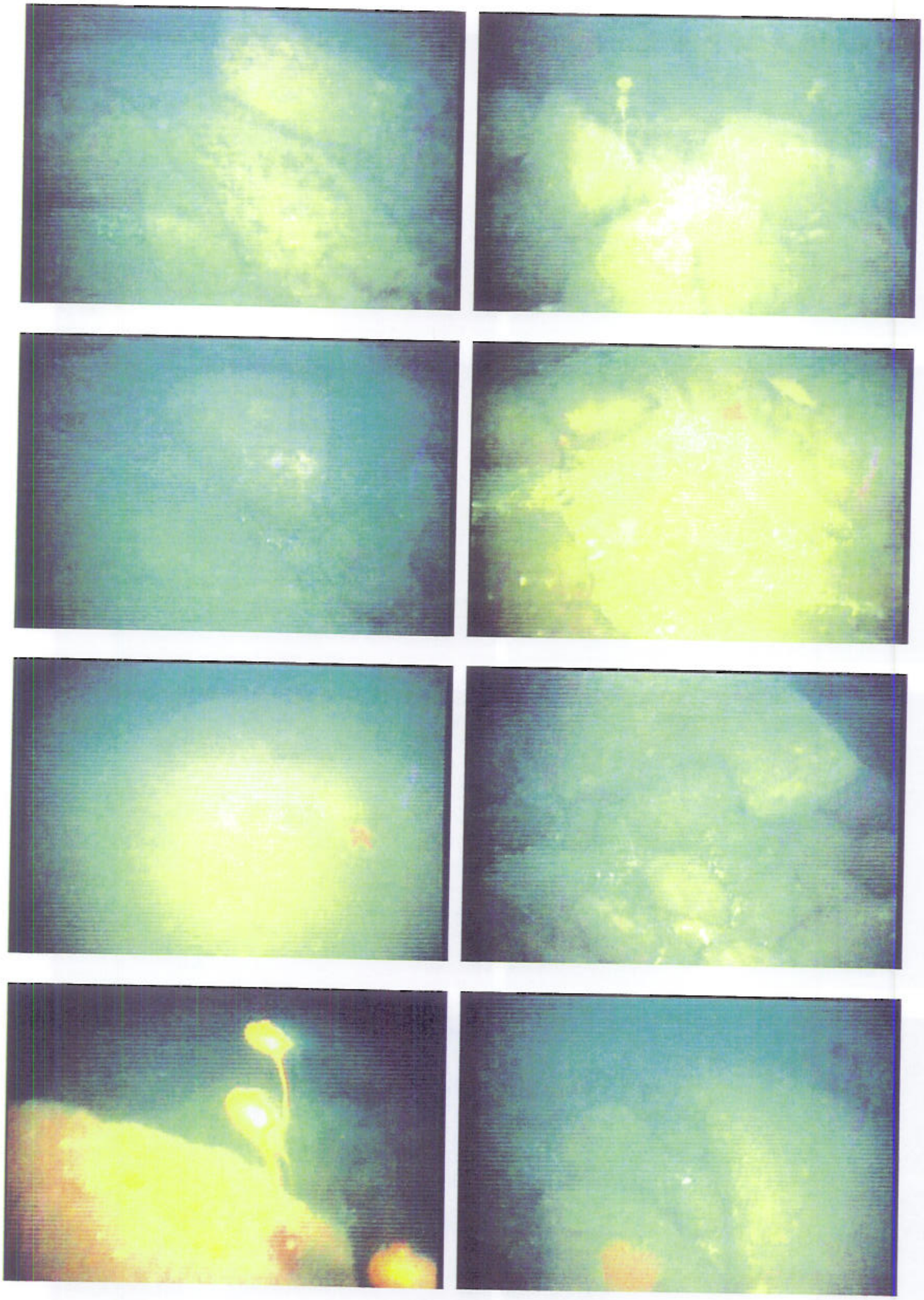
Pigeon Hills, Spring 05 representative video screen captures, Drift 6-2



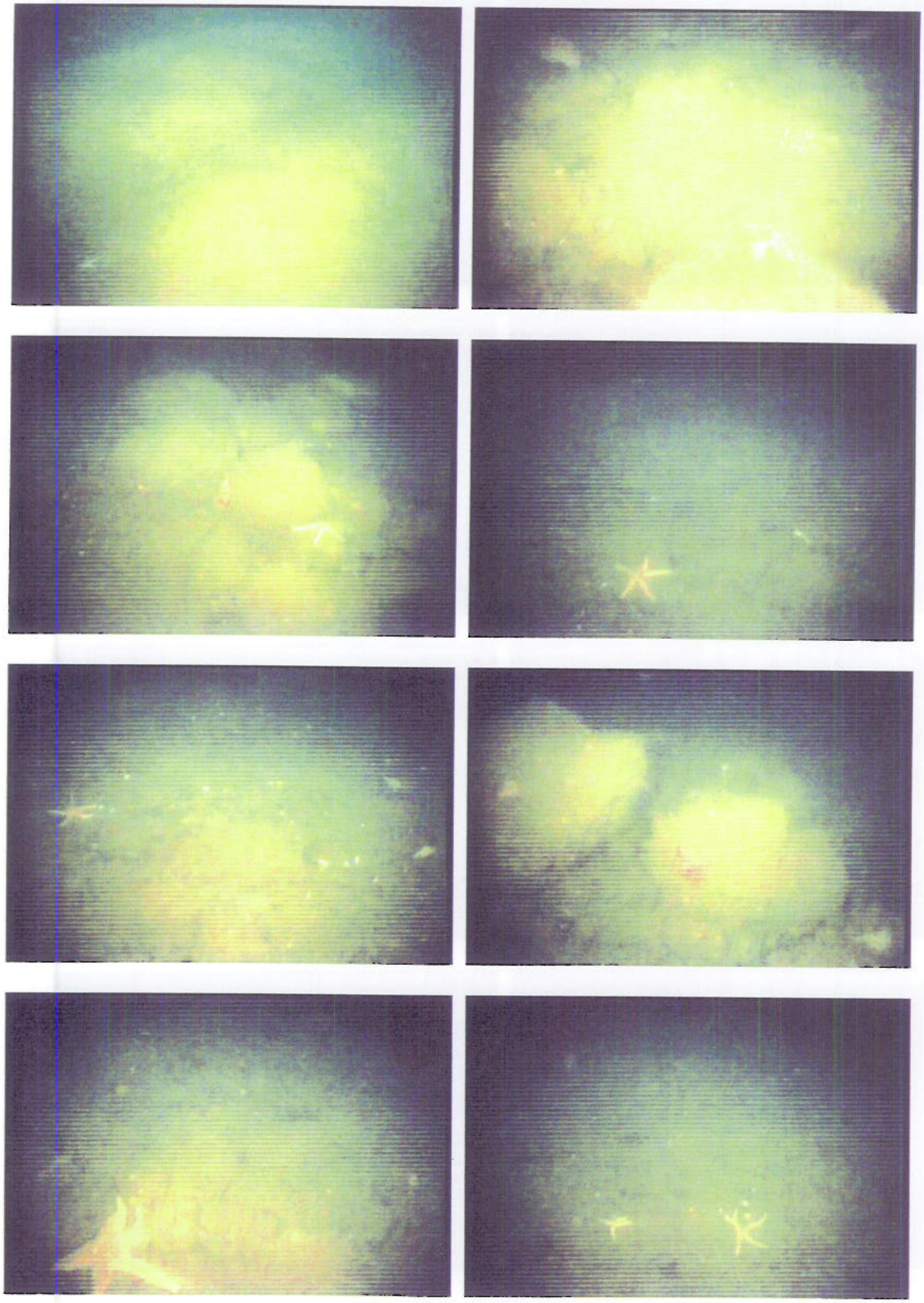
Pigeon Hills, Spring 05 representative video screen captures, Drift 7-1



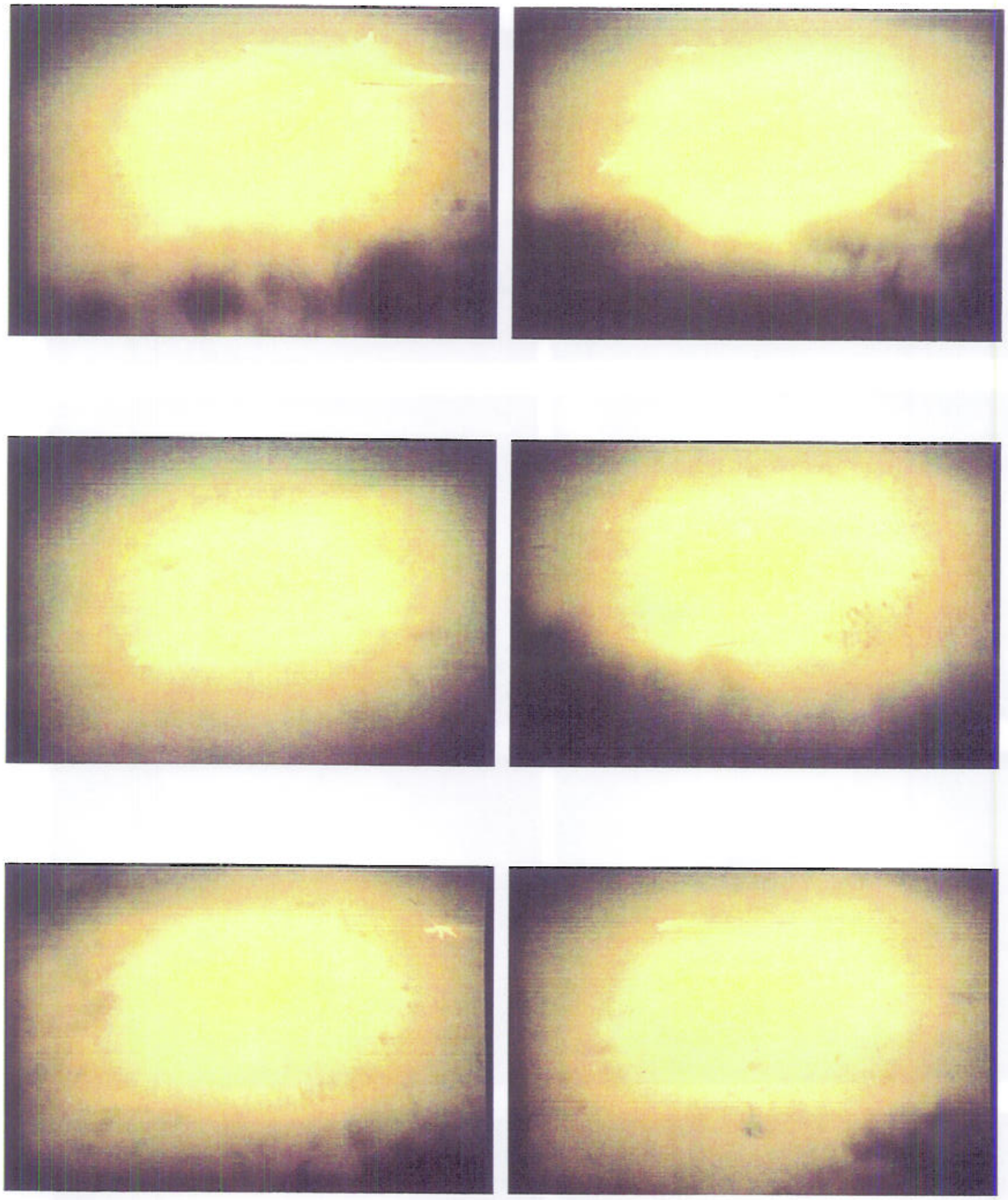
Pigeon Hills, Spring 05 representative video screen captures, Drift 7-2



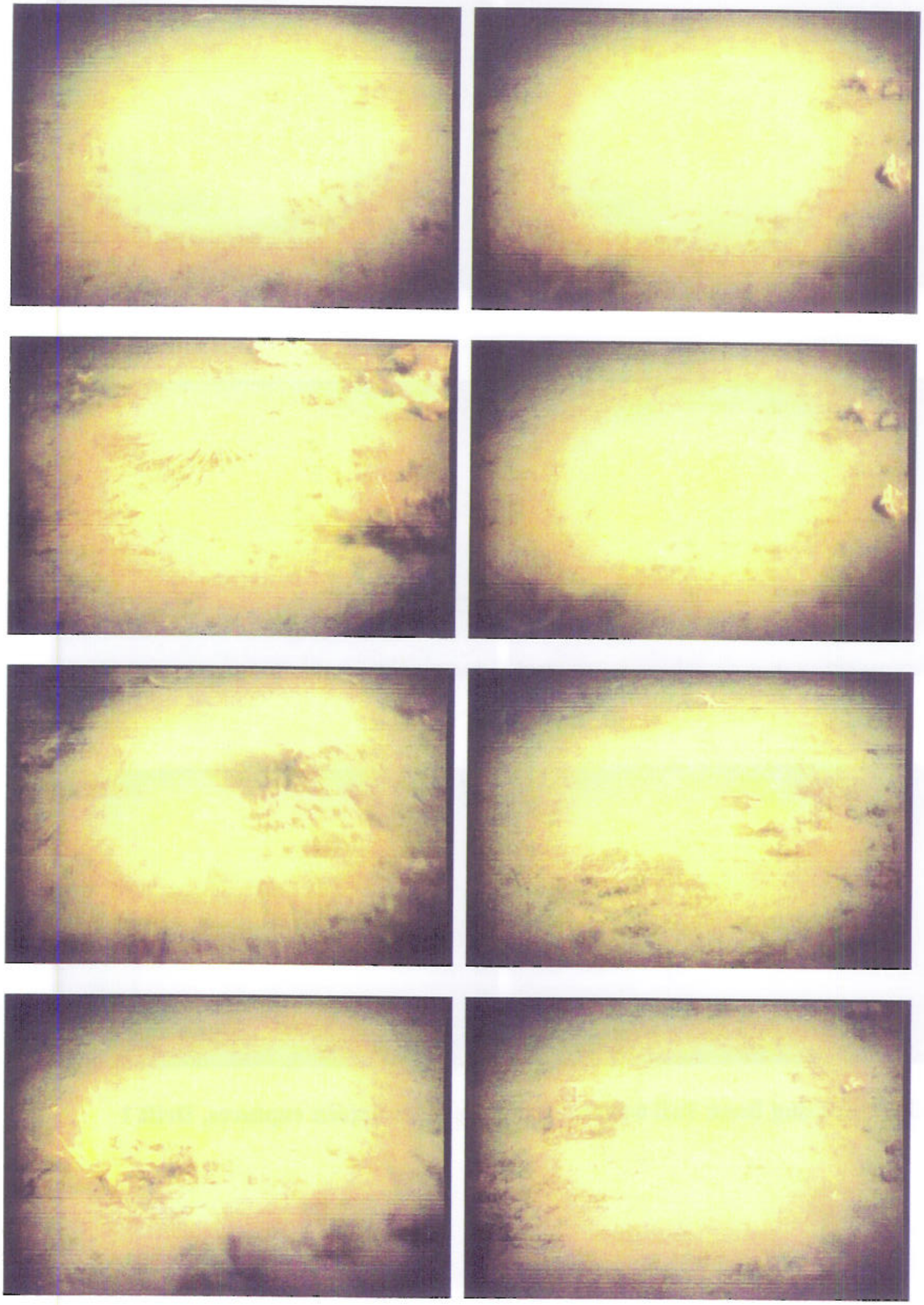
Pigeon Hills, Spring 05 representative video screen captures, Drift 8-1



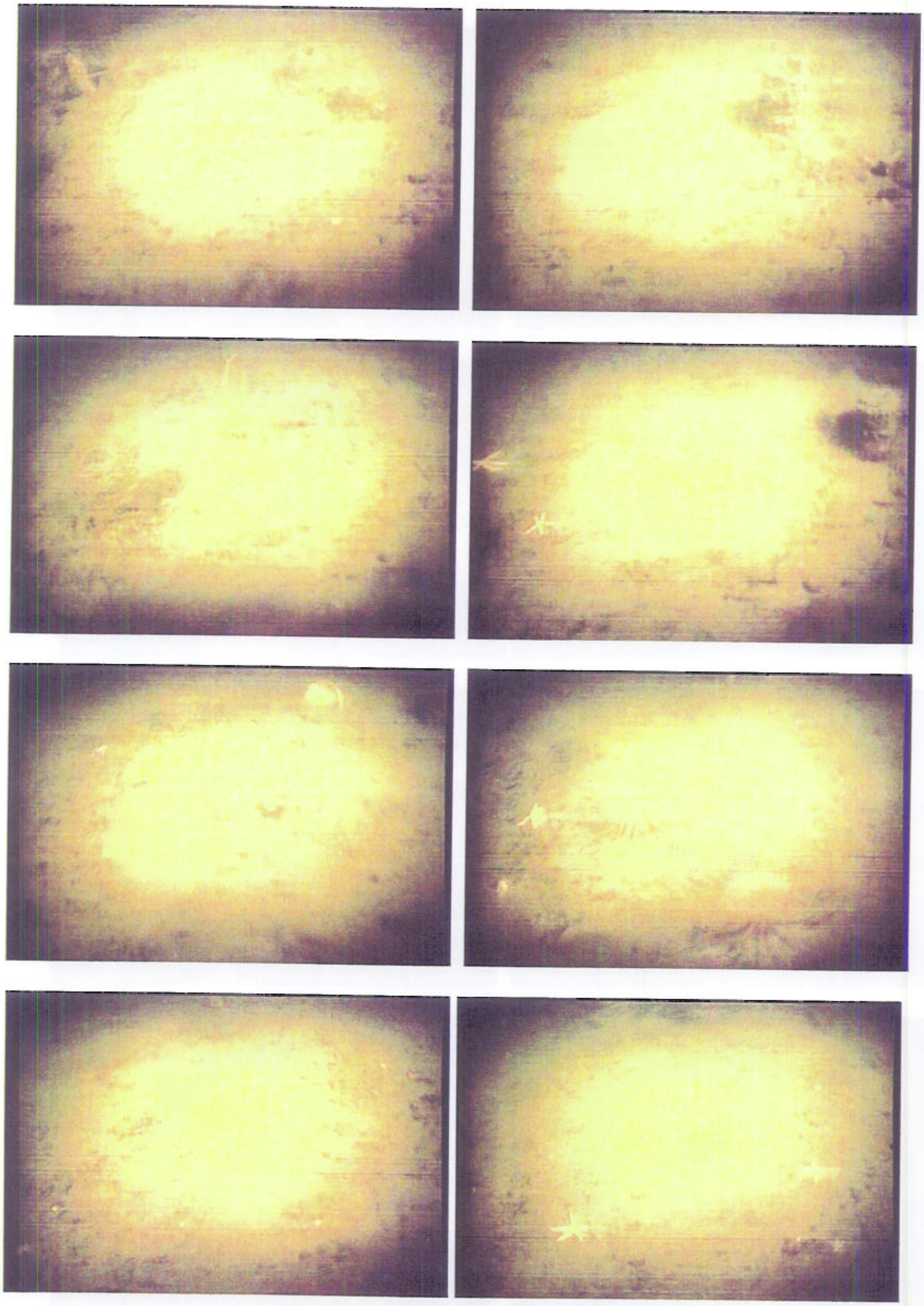
Pigeon Hills, Spring 05 representative video screen captures, Drift 8-2



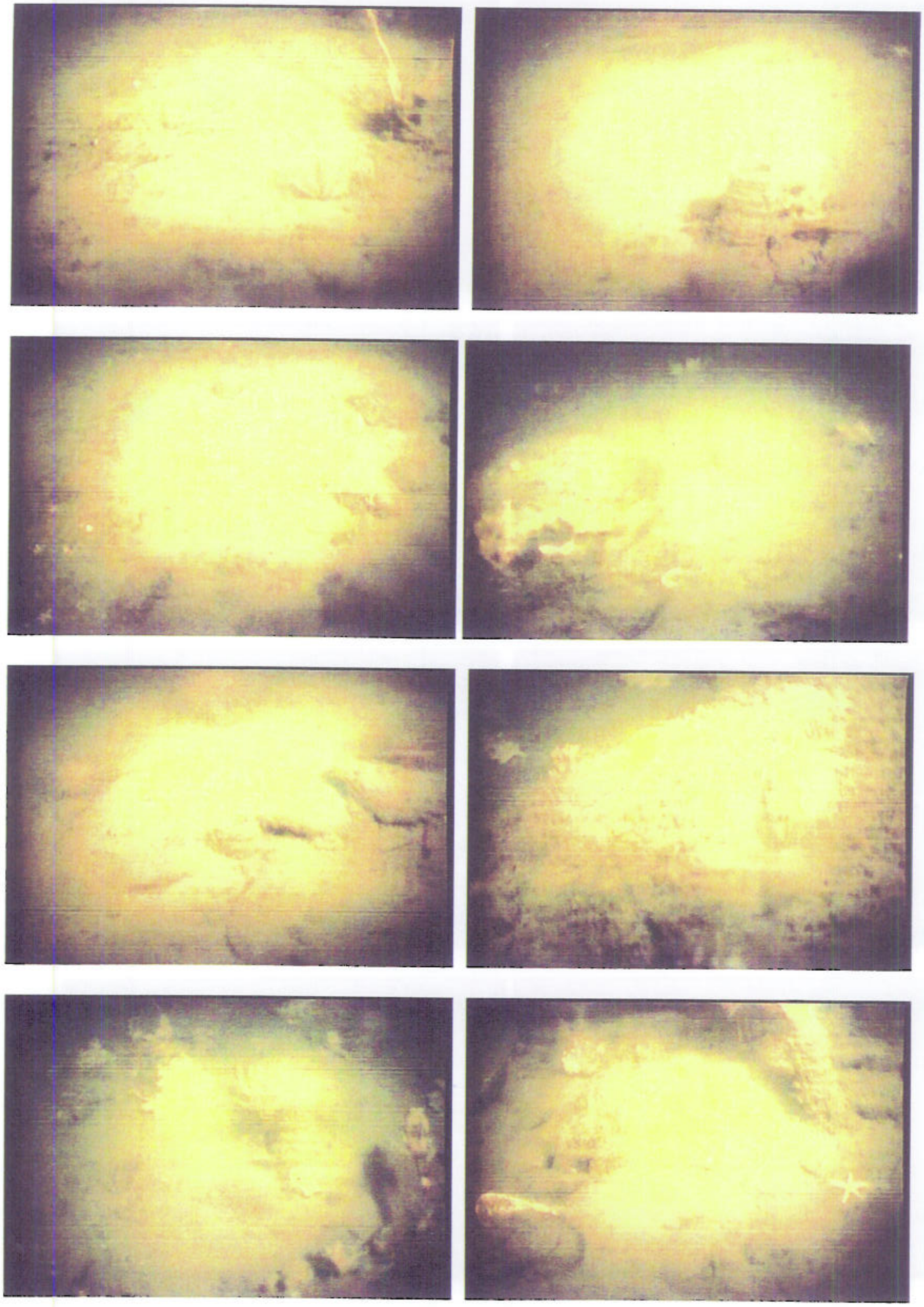
Stellwagen/Long Bank Fall 04 representative video screen captures, Drift 1



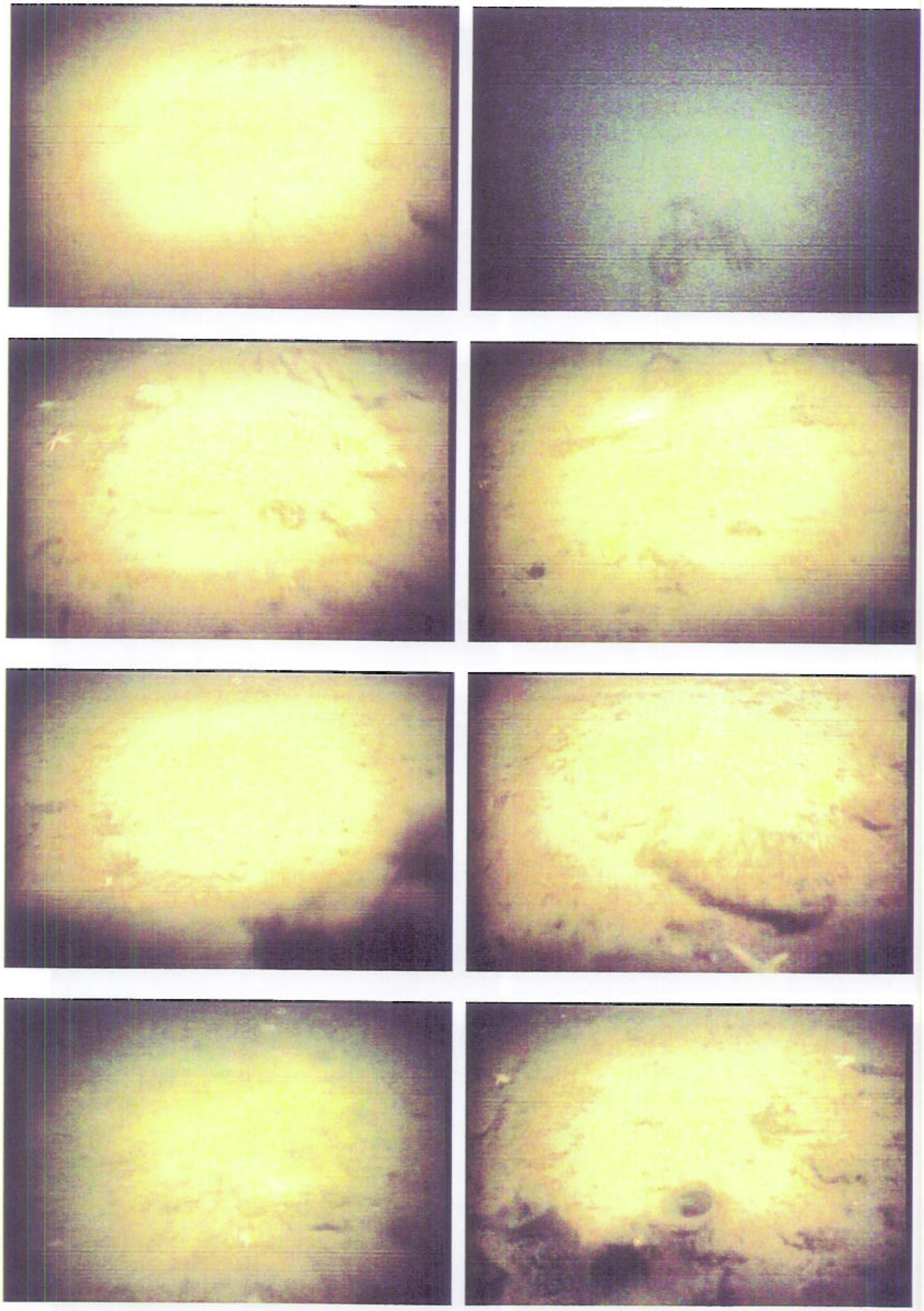
Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 2-1



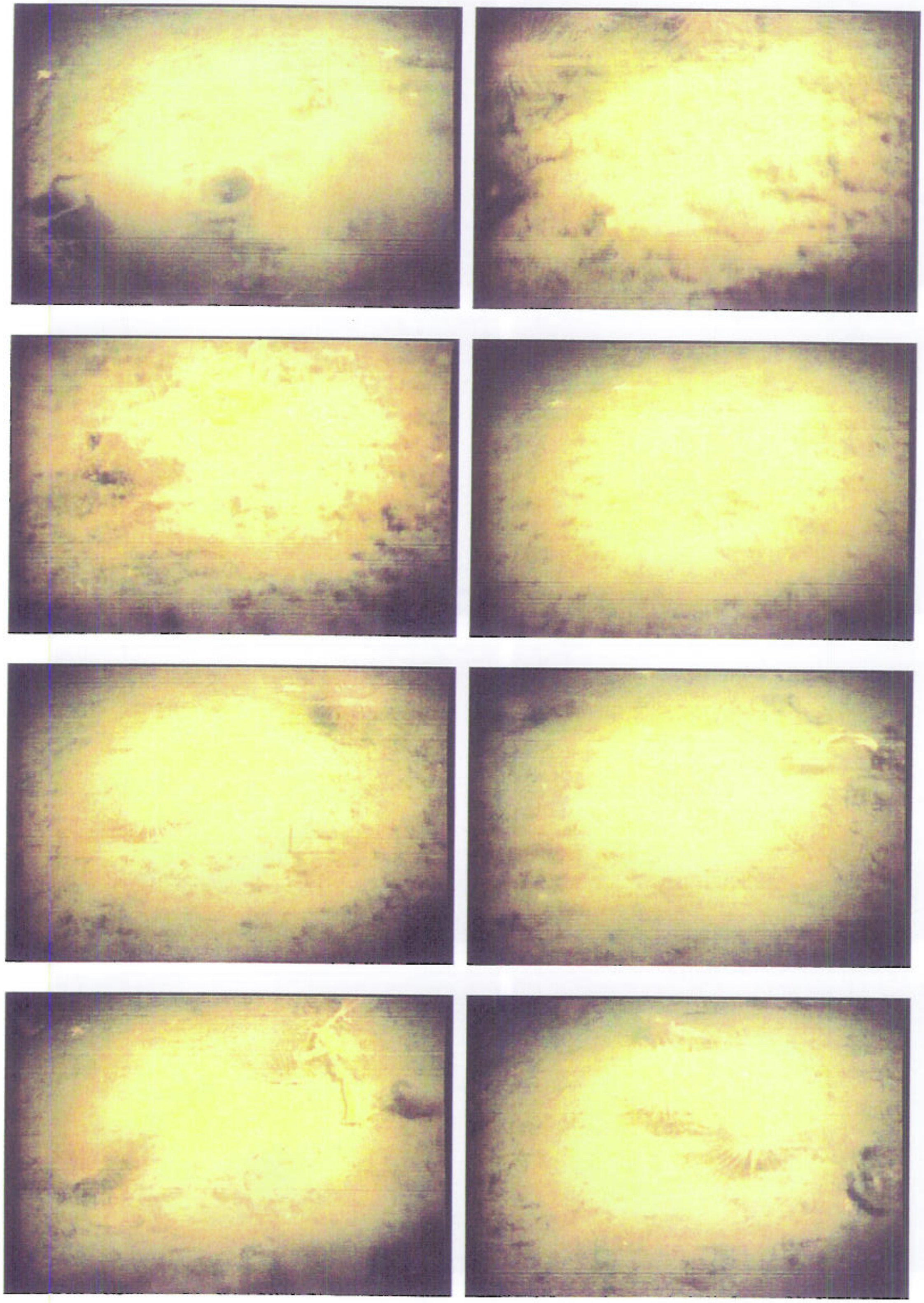
Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 2-2



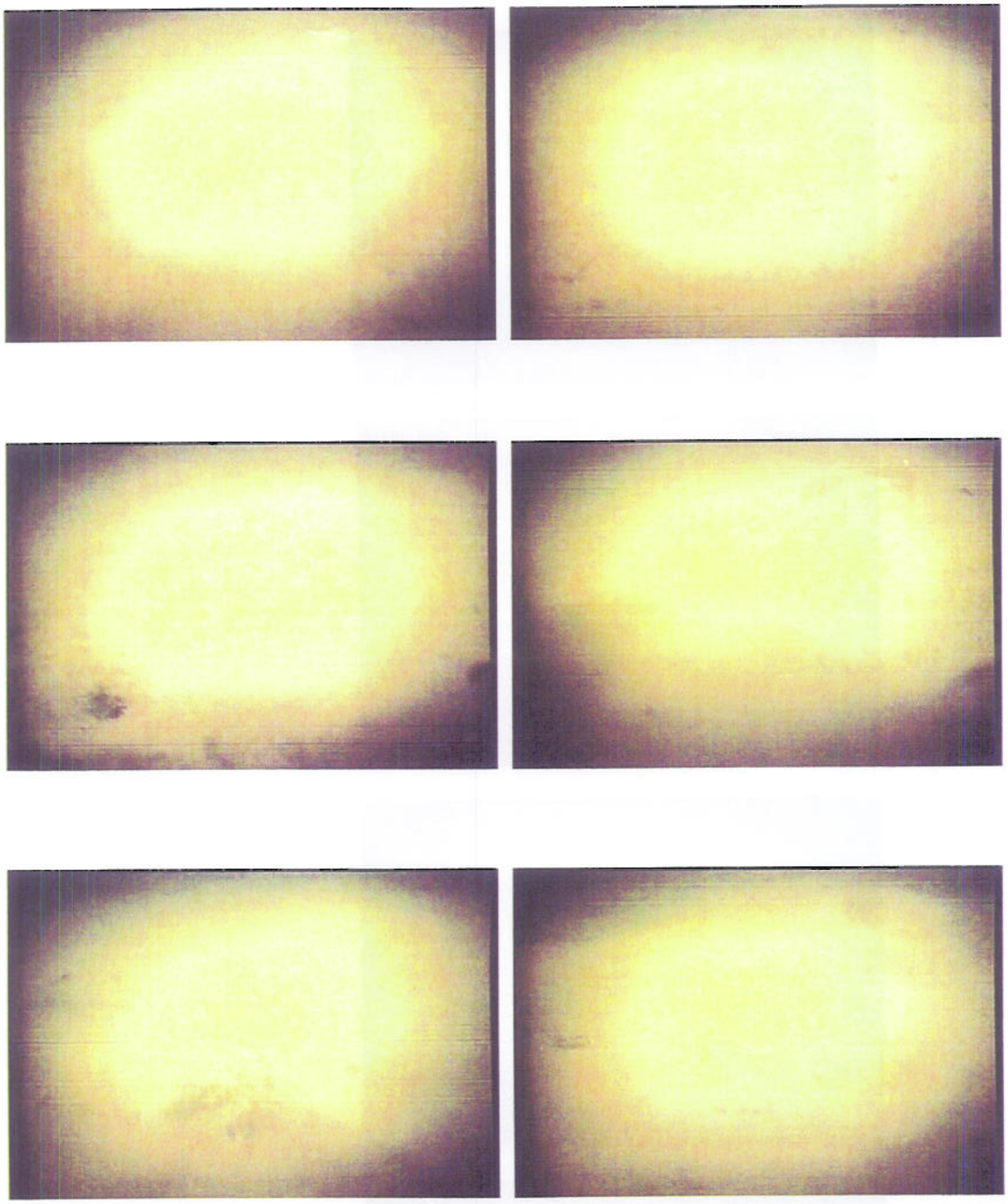
Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 2-3



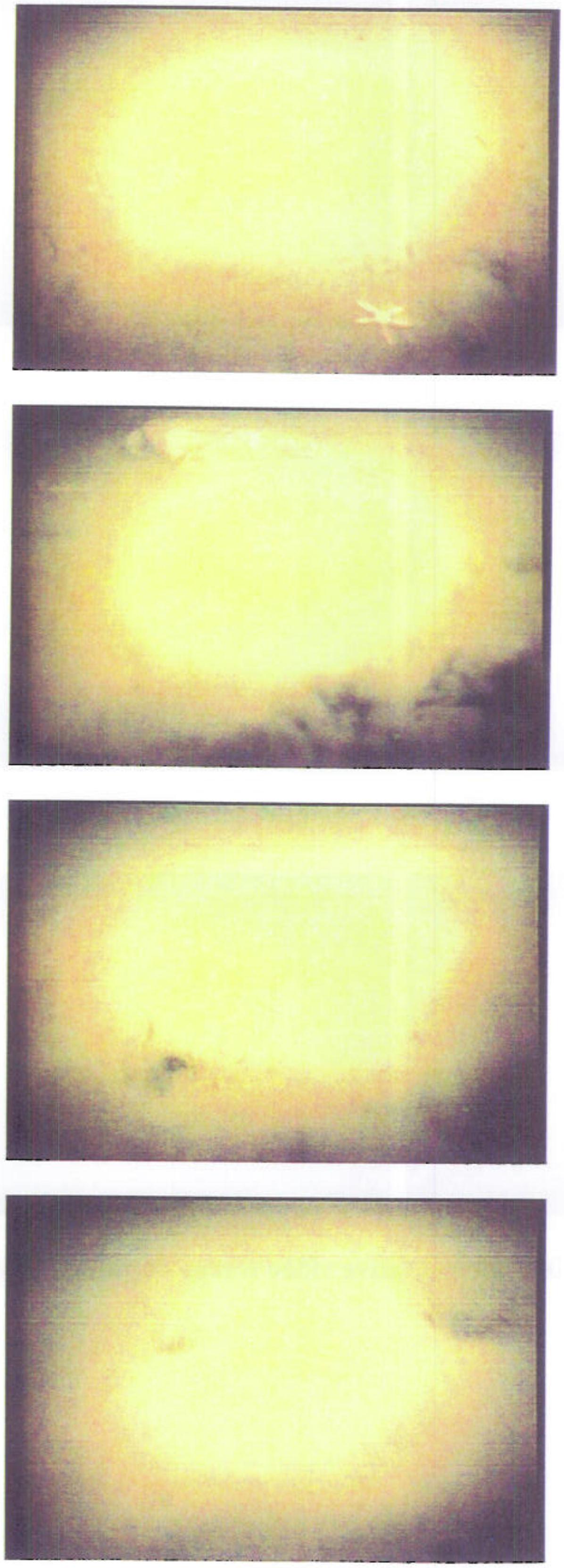
Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 3-1



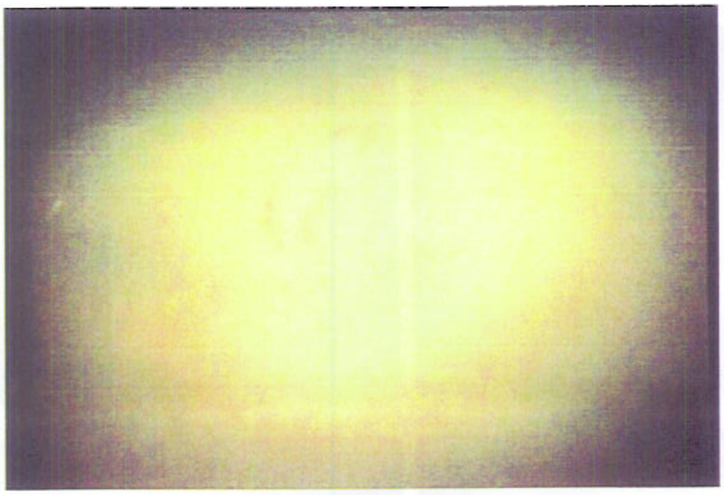
Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 3-2

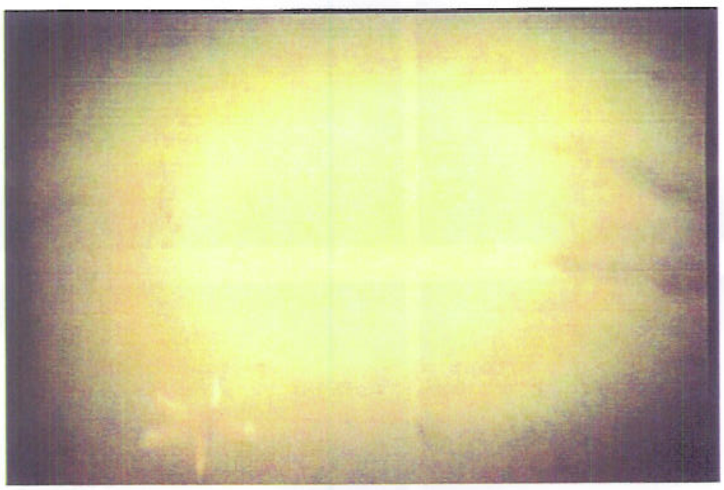


Stellwagen/Long Bank Fall 04 representative video screen captures, Drift 4

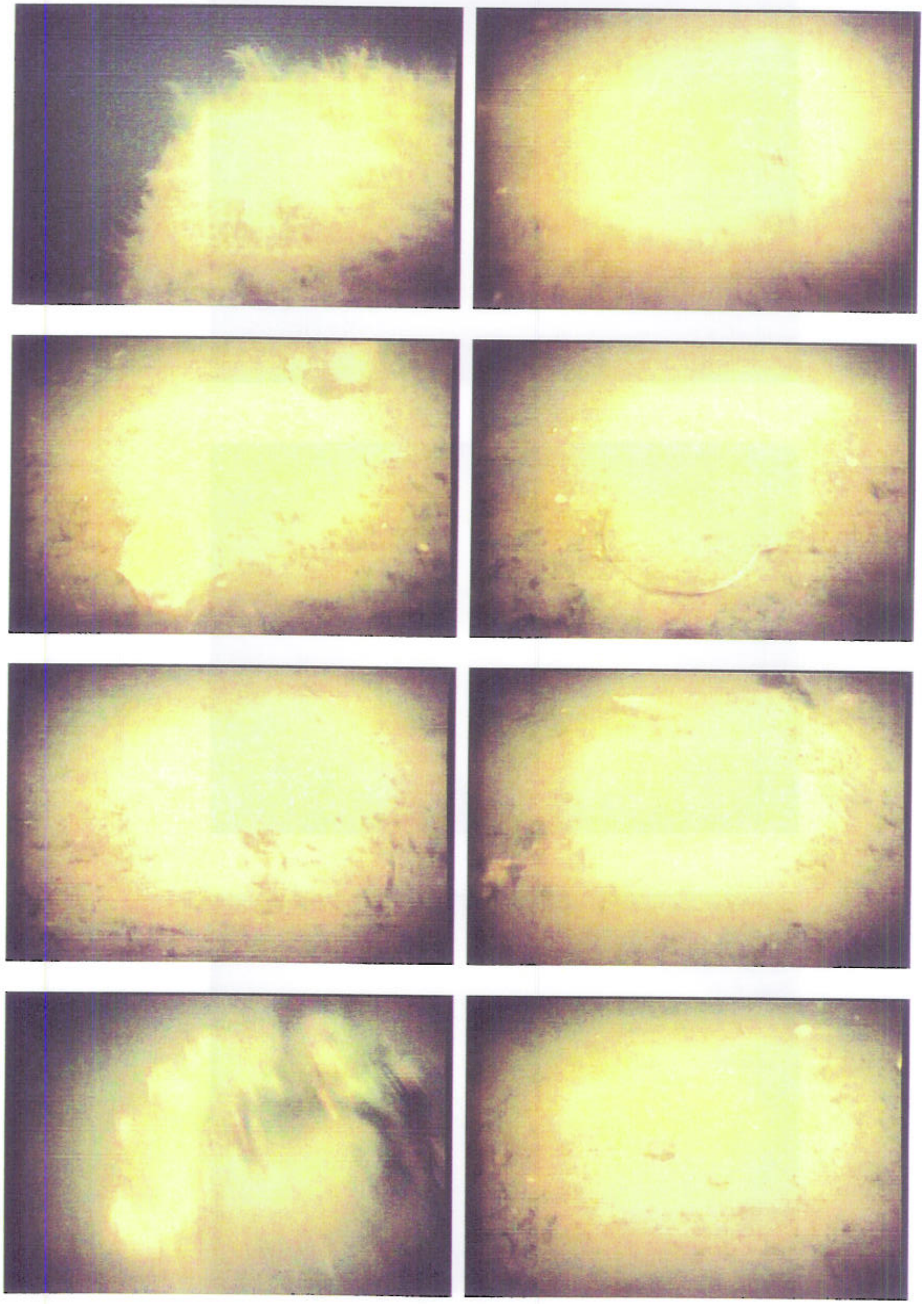


Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 5

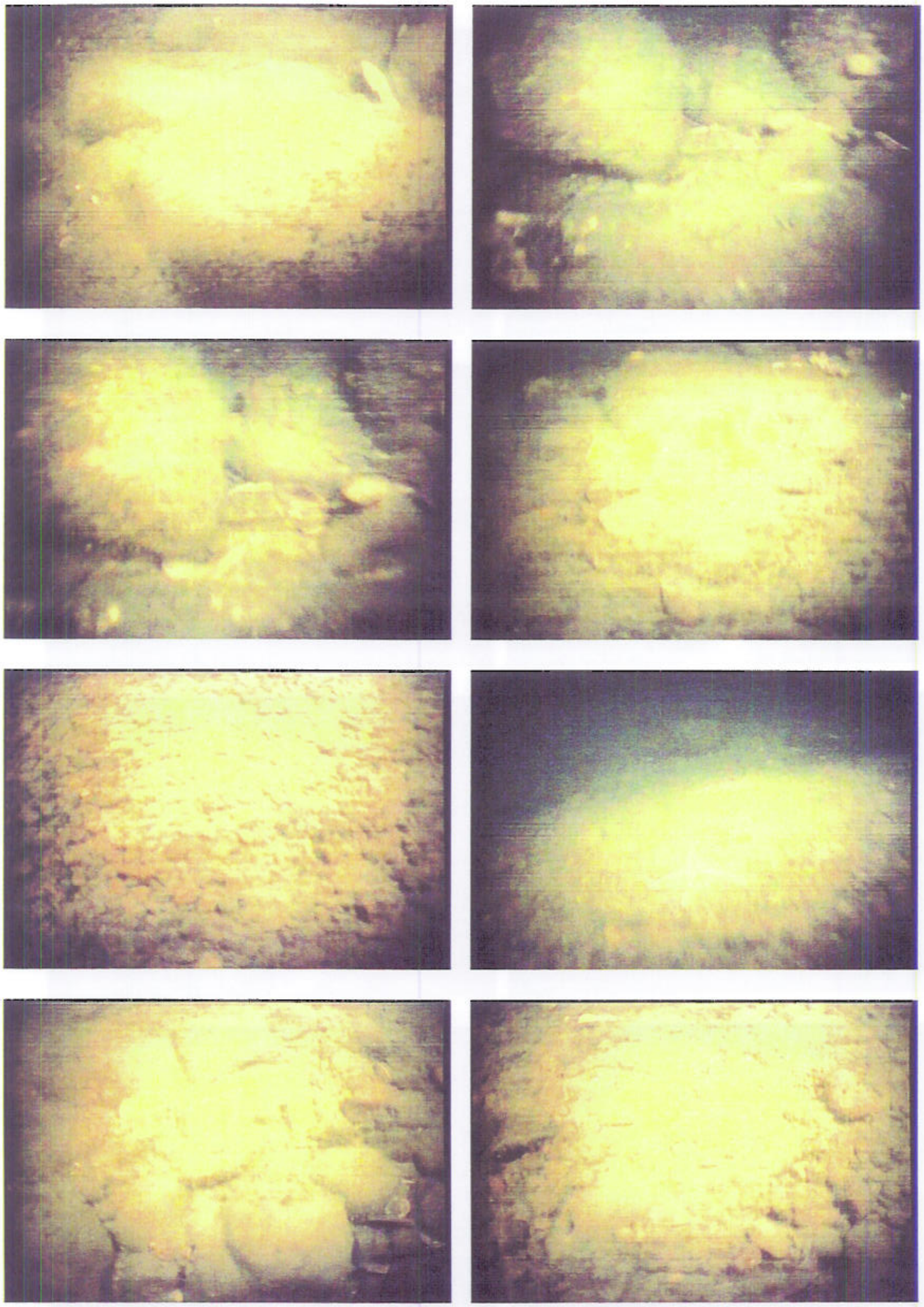




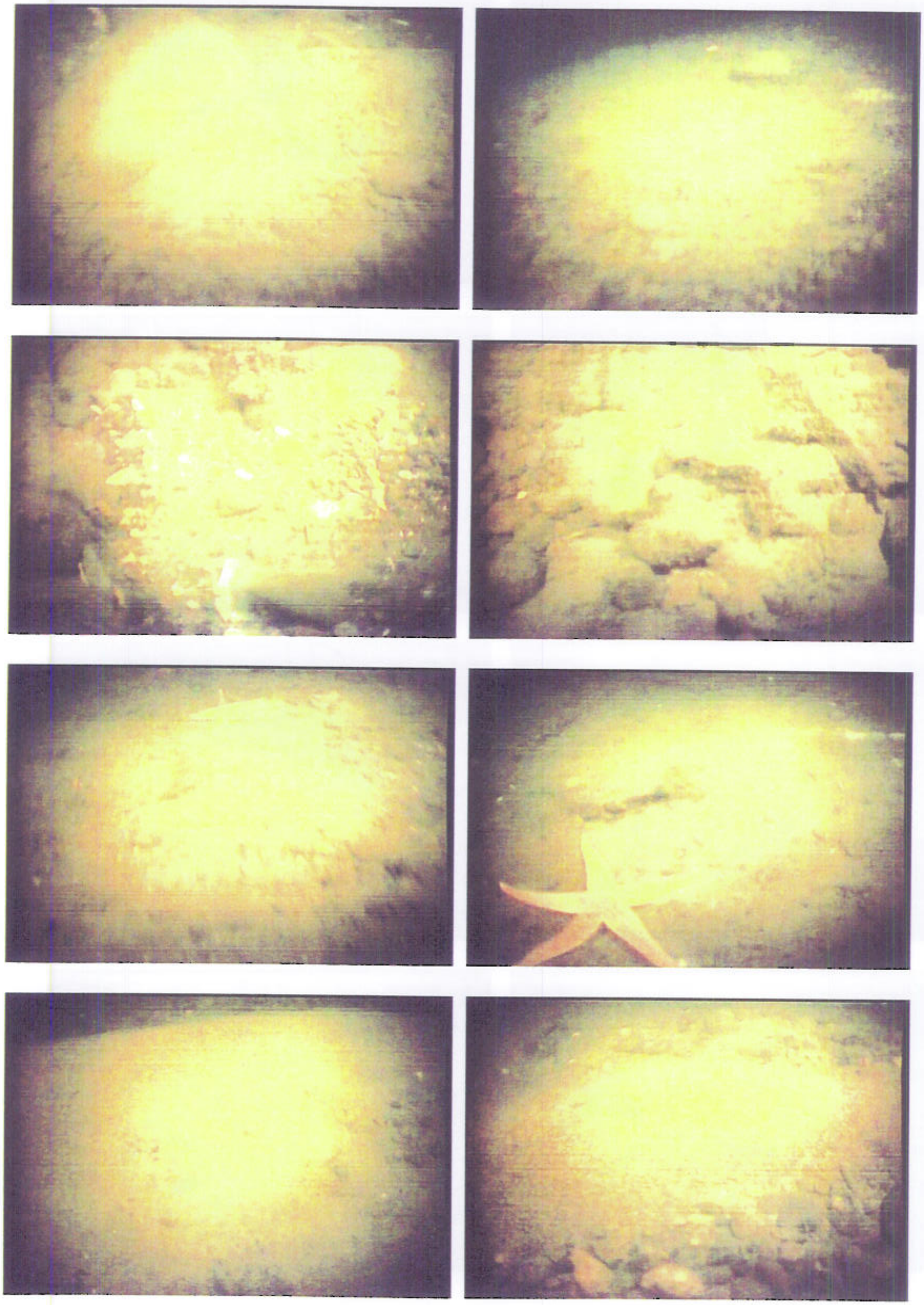
Stellwagen/Long Bank Fall 04 representative screen captures, Drift 6



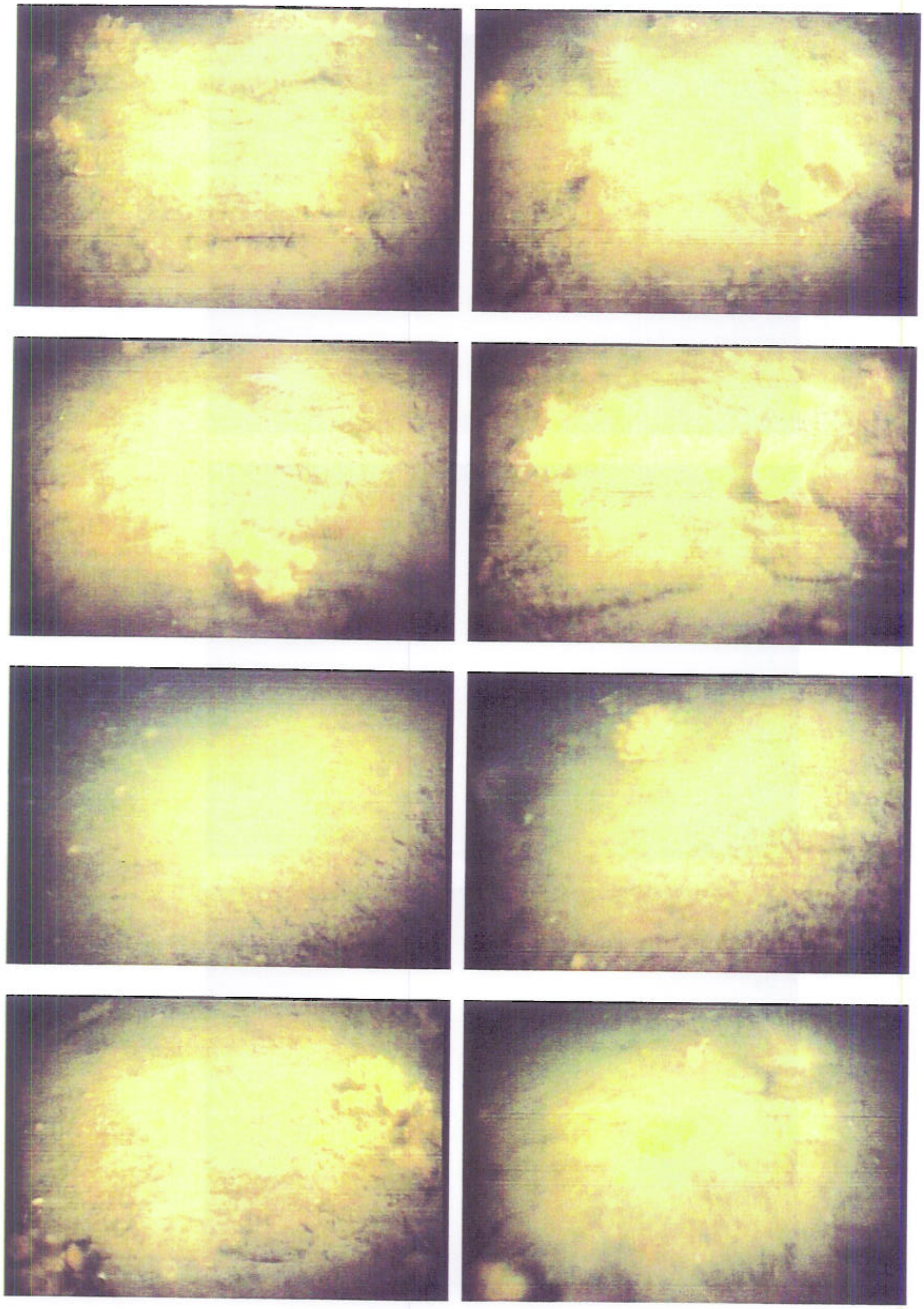
Stellwagen/Long Bank Fall 04 representative video screen captures, Drift 7



Stellwagen/Long Bank Fall 04 representative video screen captures, Drift 8-1

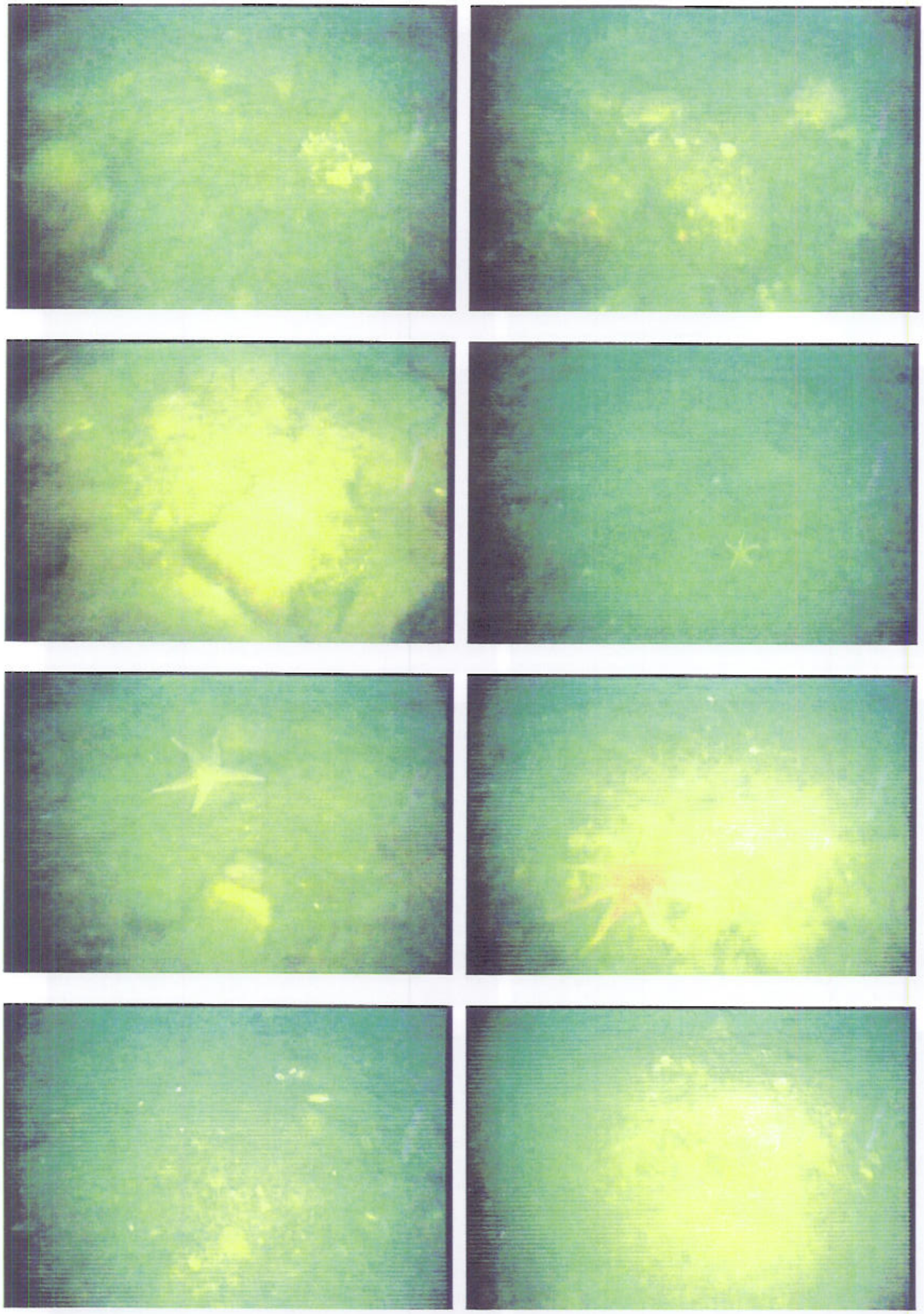


Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 8-2

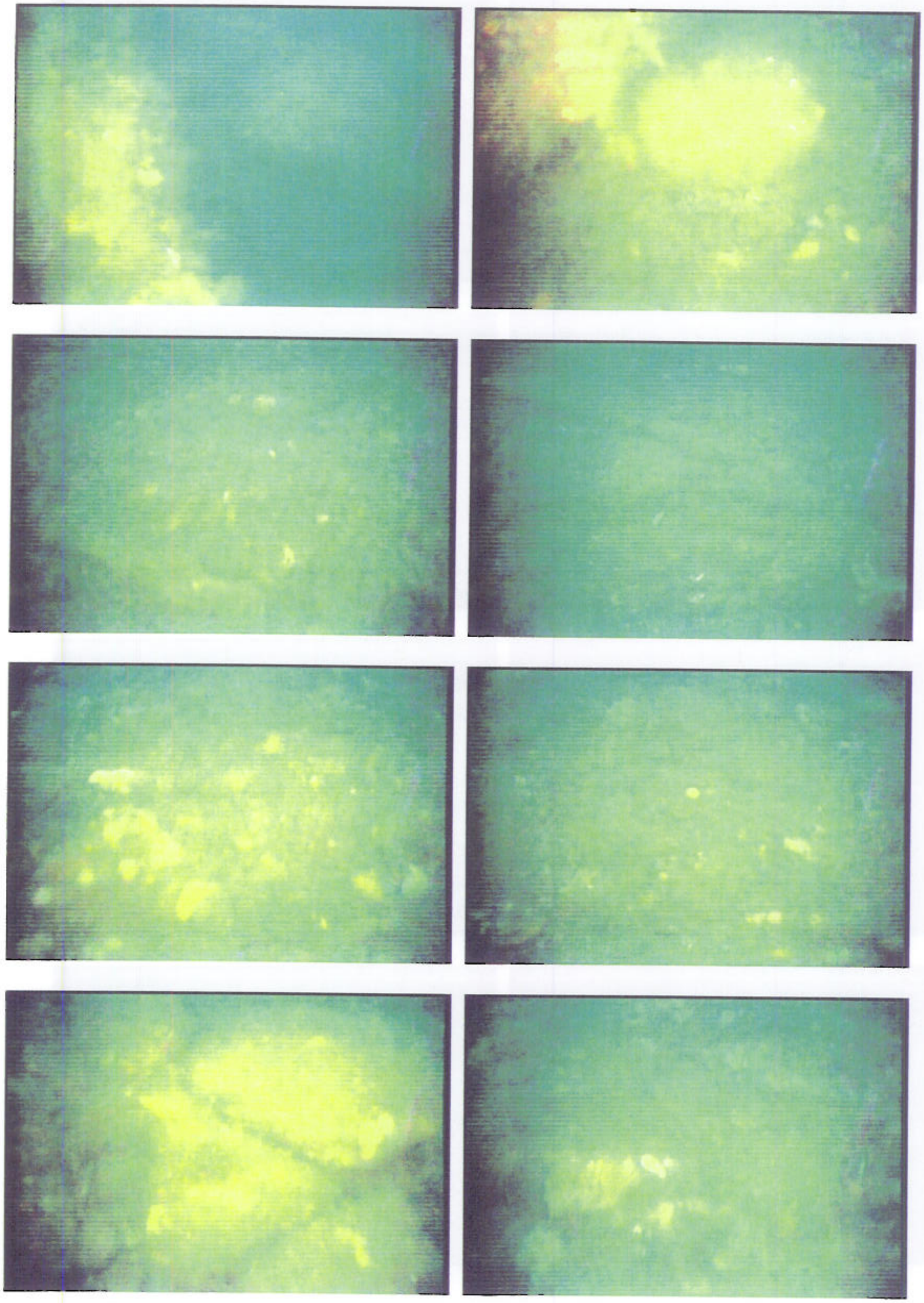


Stellwagen/Long Bank, Fall 04 representative video screen captures, Drift 9-2

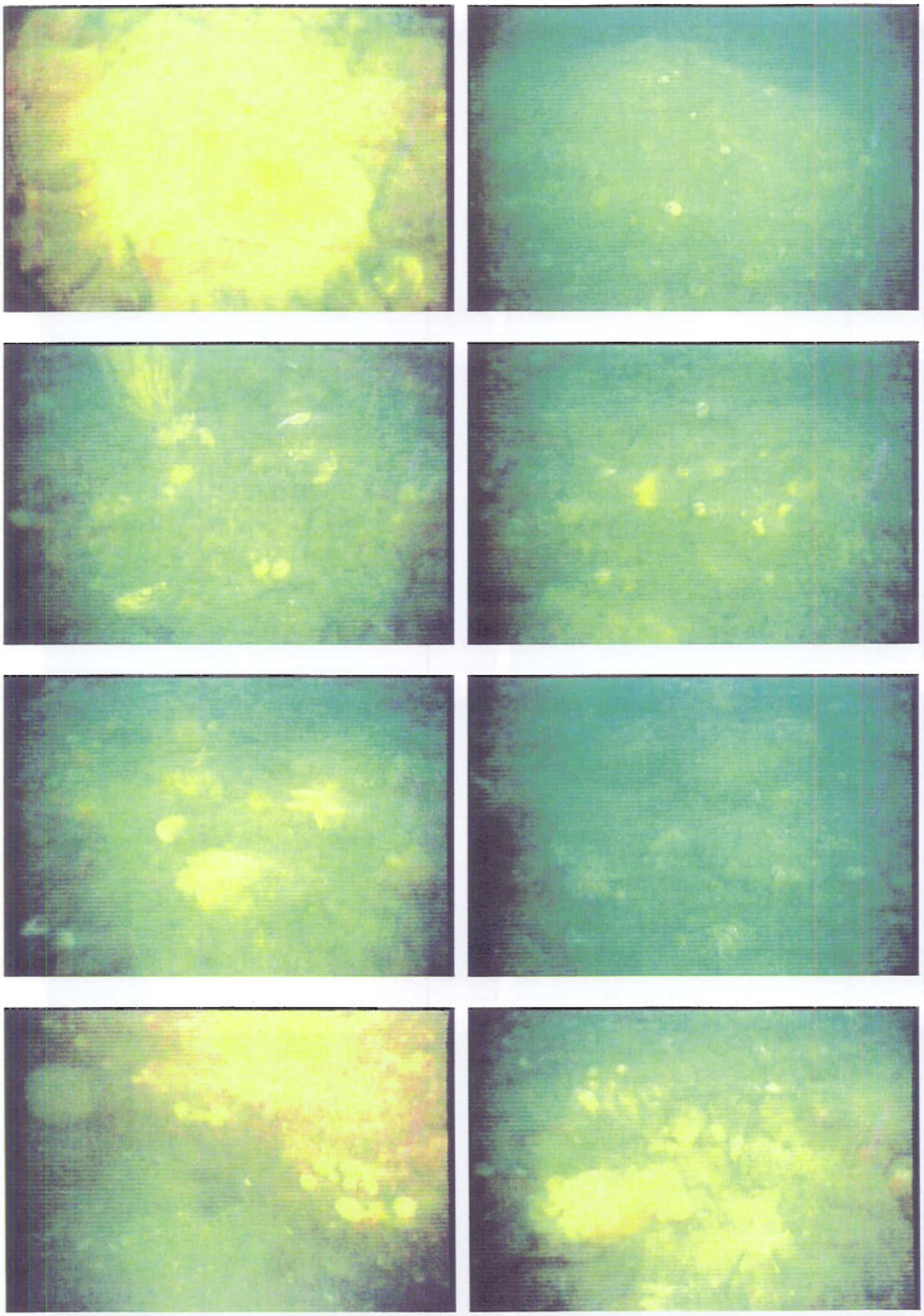
Stellwagen/Long Bank Spring 05 representative video screen captures, Drift 3



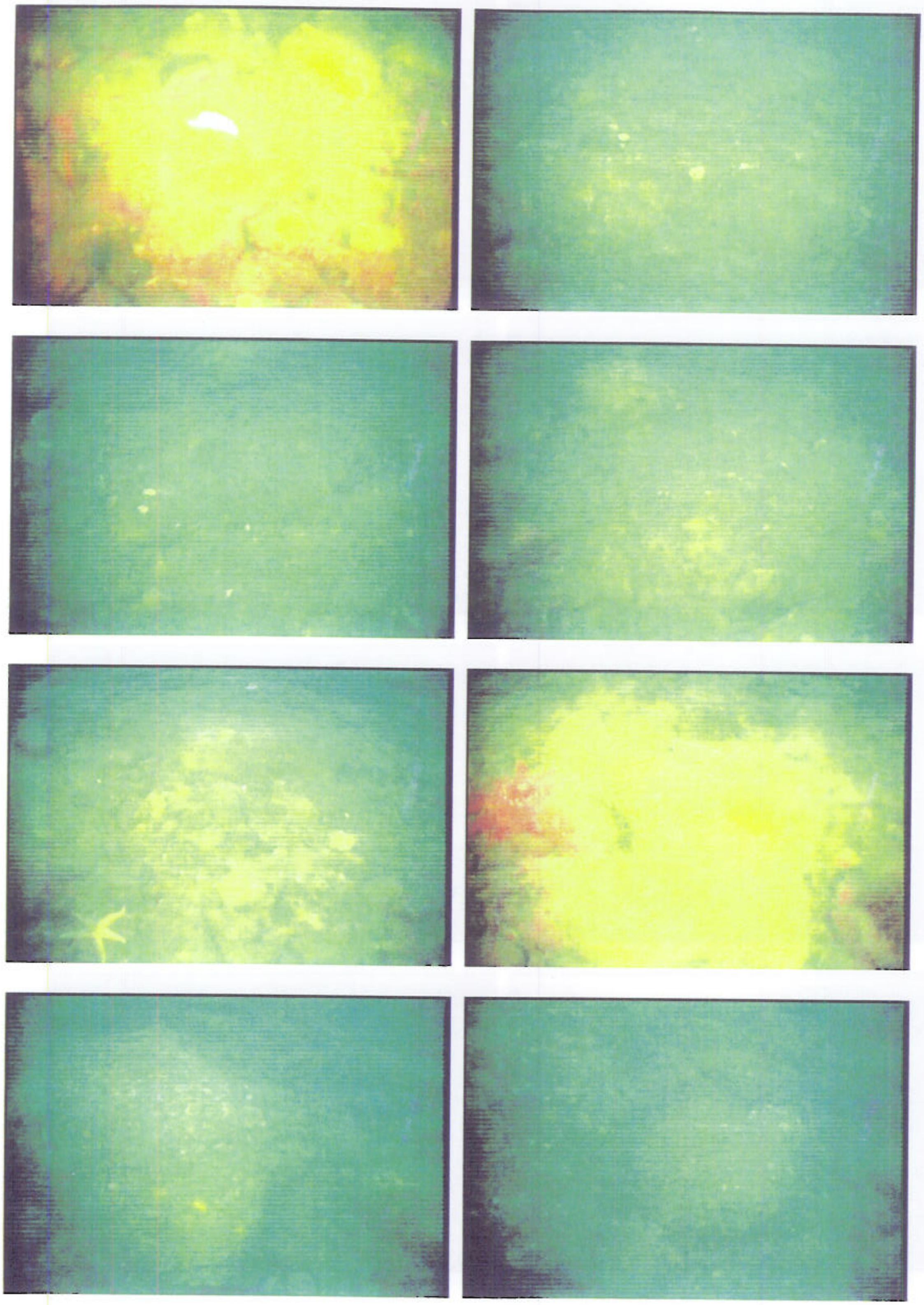
Stellwagen/Long Bank, Spring 05 representative video screen captures, Drift 4



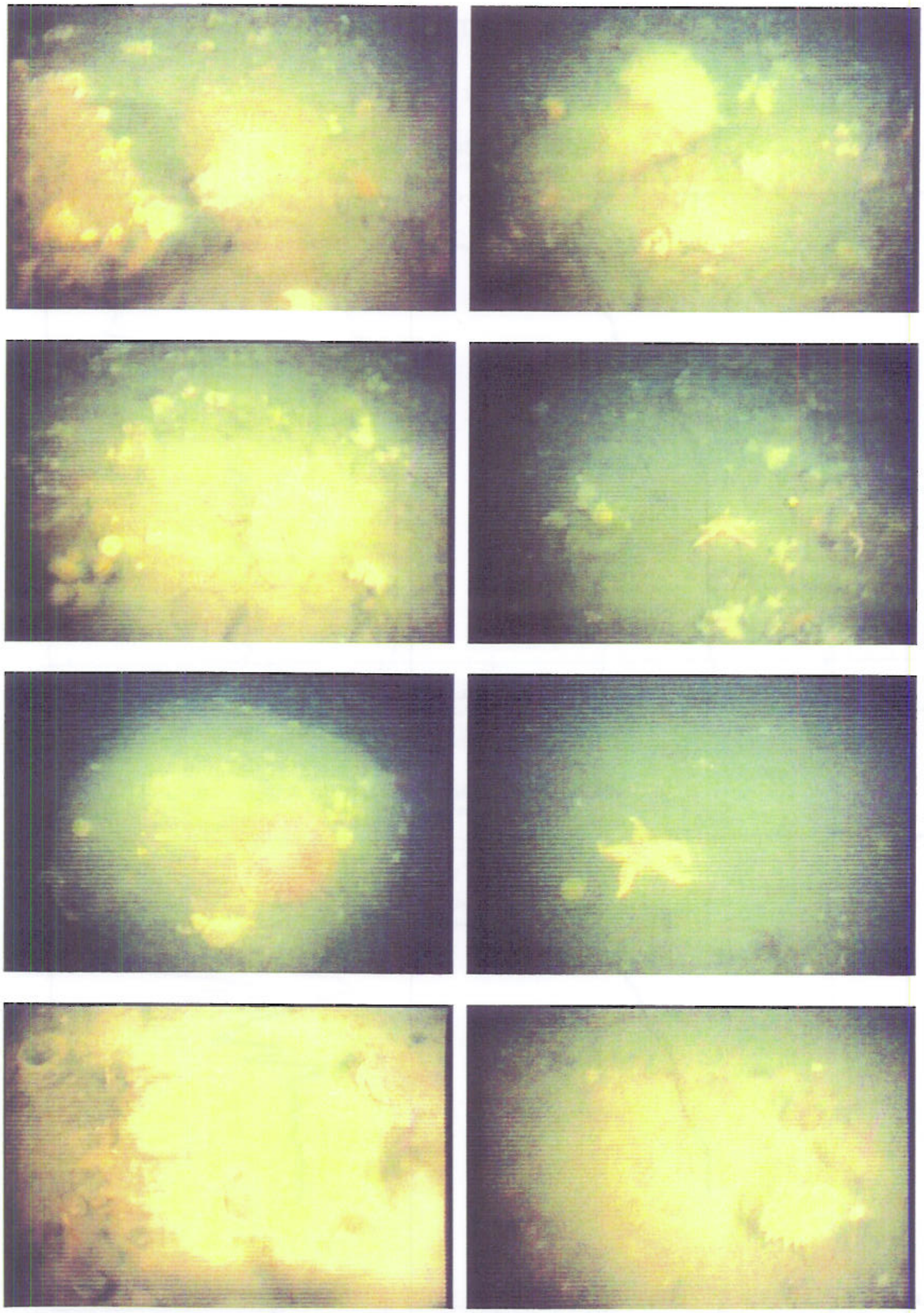
Stellwagen/Long Bank, Spring 05 representative video screen captures, Drift 5-1



Stellwagen/Long Bank, Spring 05 representative video screen captures, Drift 5-2



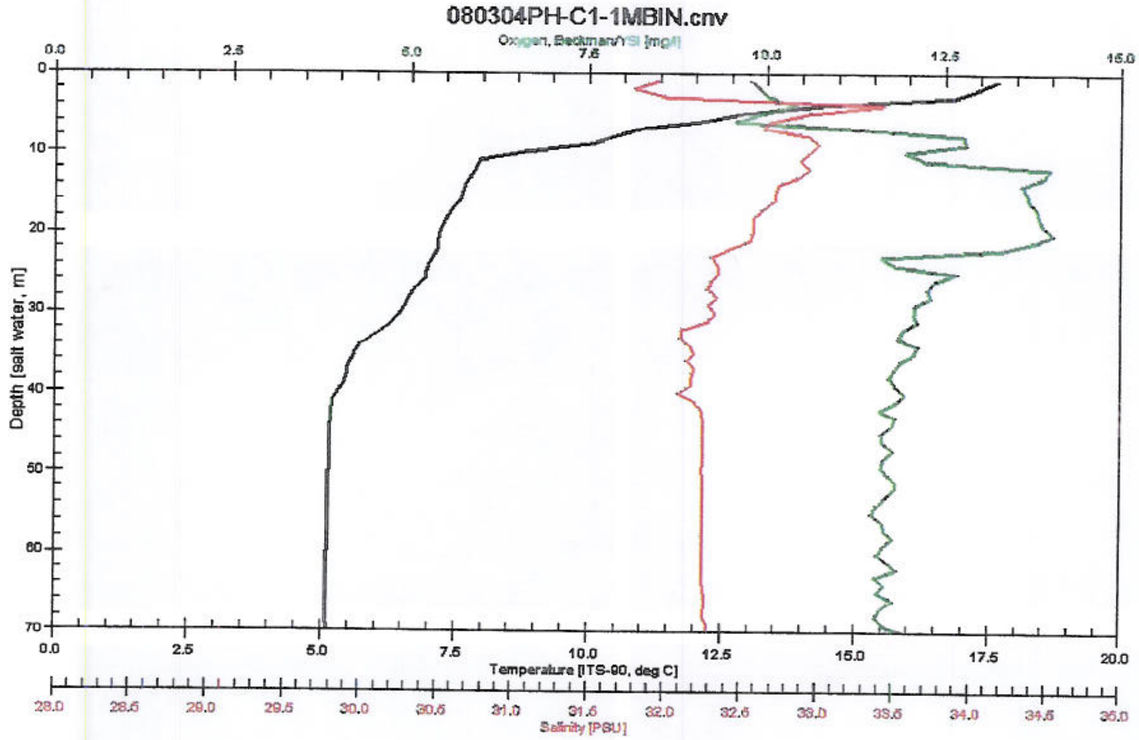
Stellwagen/Long Bank, Spring 05 representative video screen captures, Drift 7

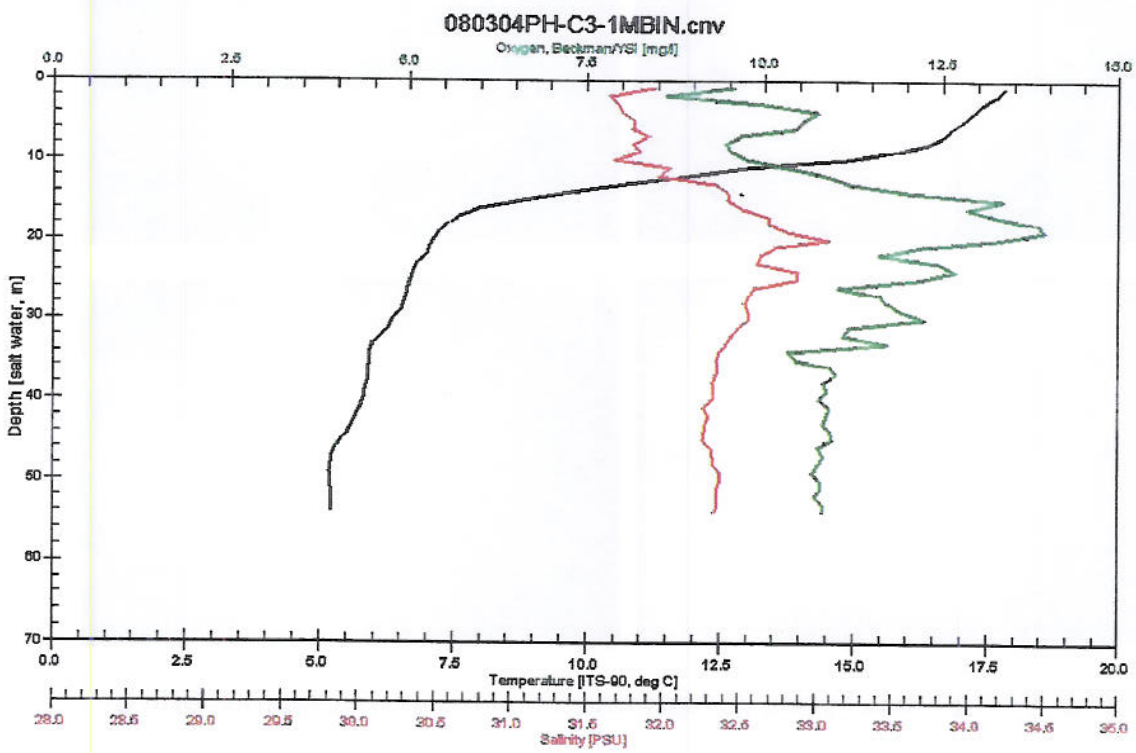


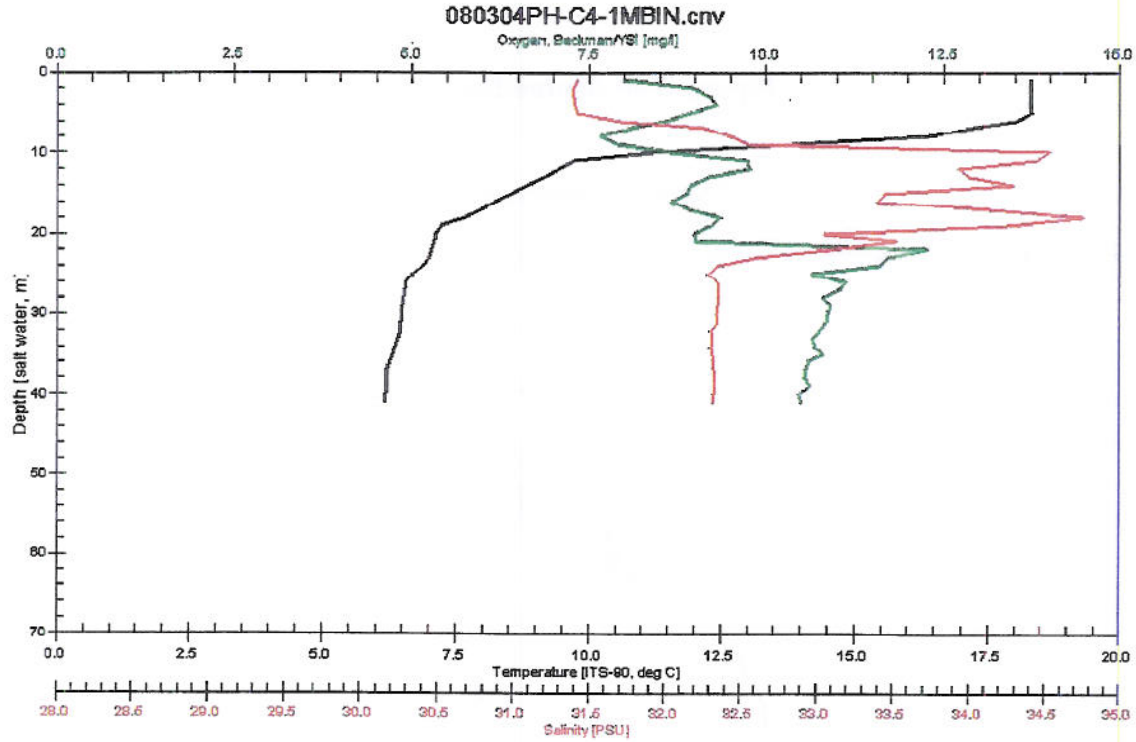
Stellwagen/Long Bank, Spring 05 representative video screen captures, Drift 8

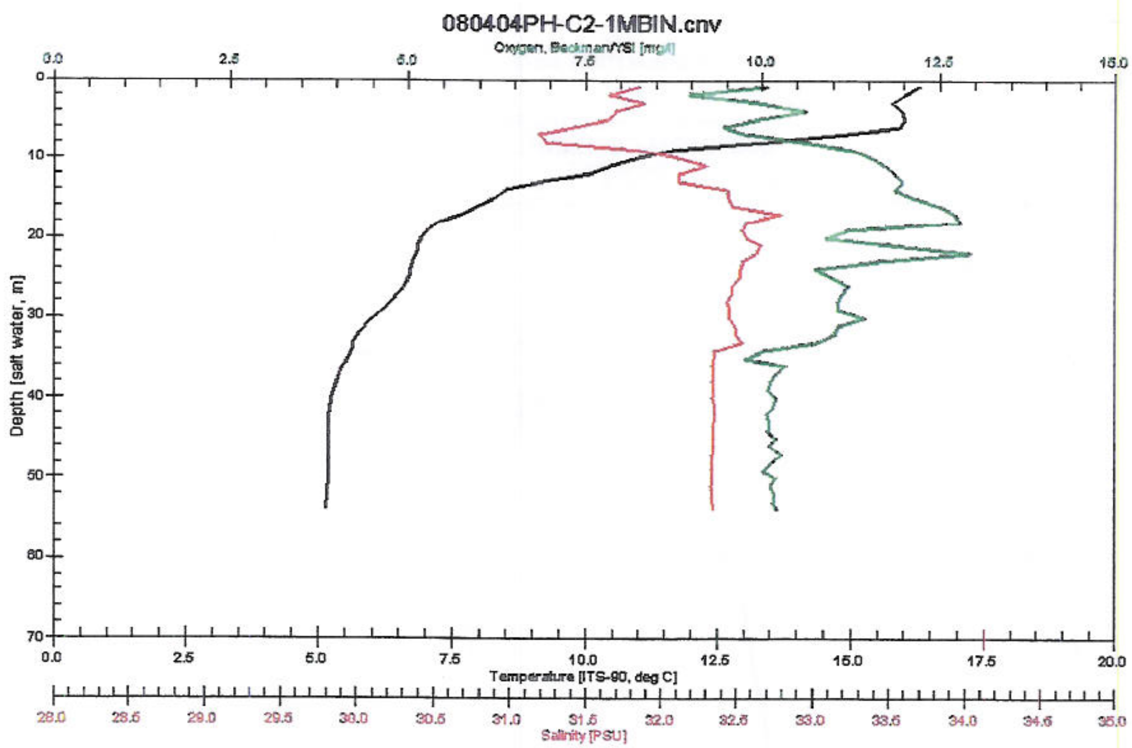
APPENDIX D. CTD PROFILES

Pigeon Hills August

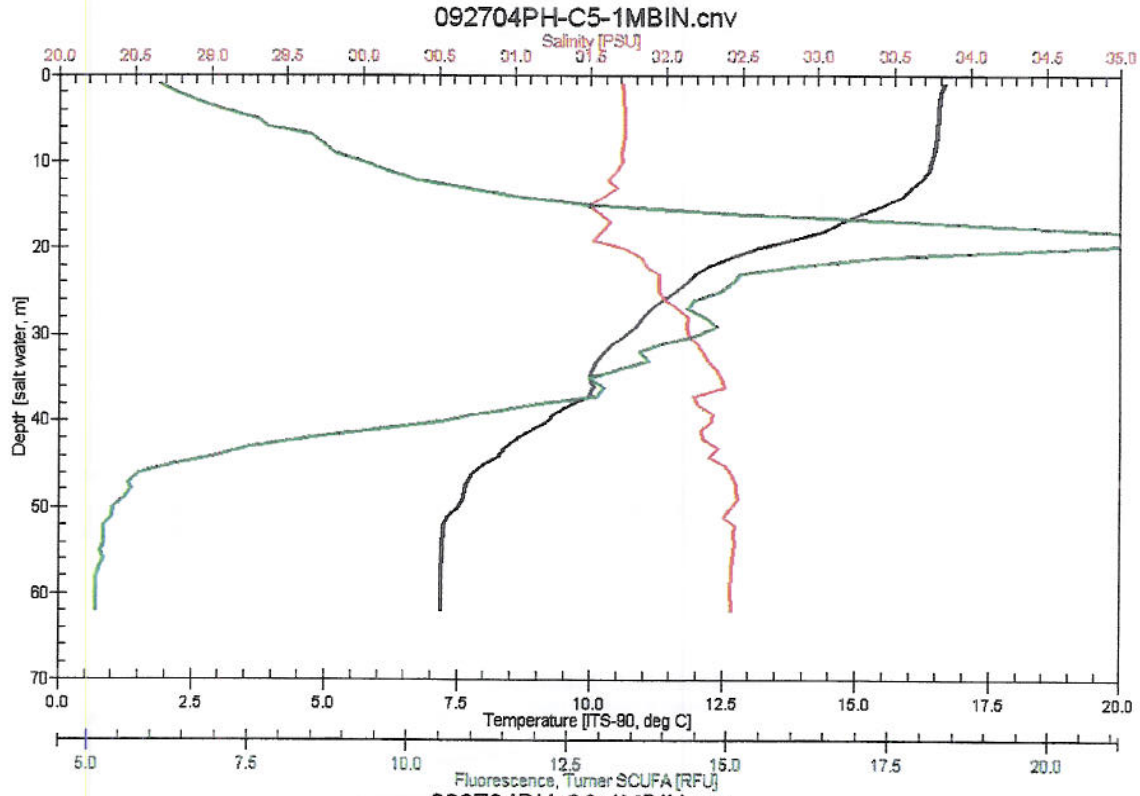


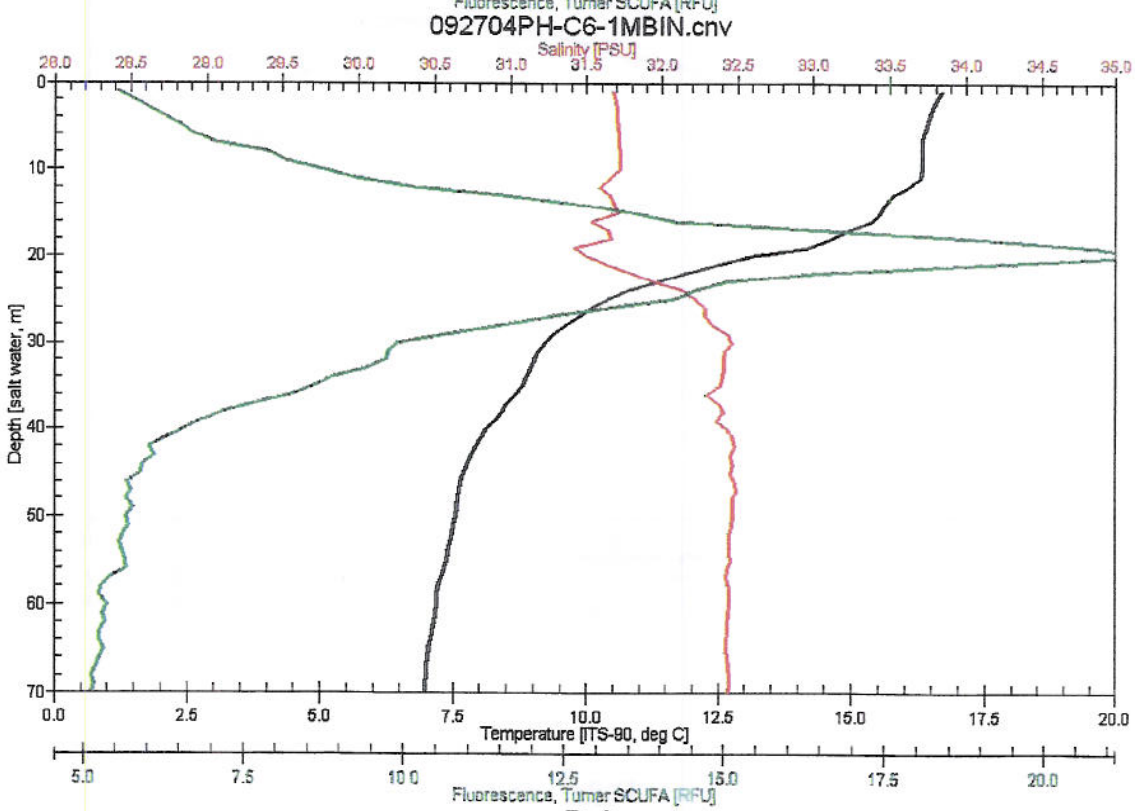


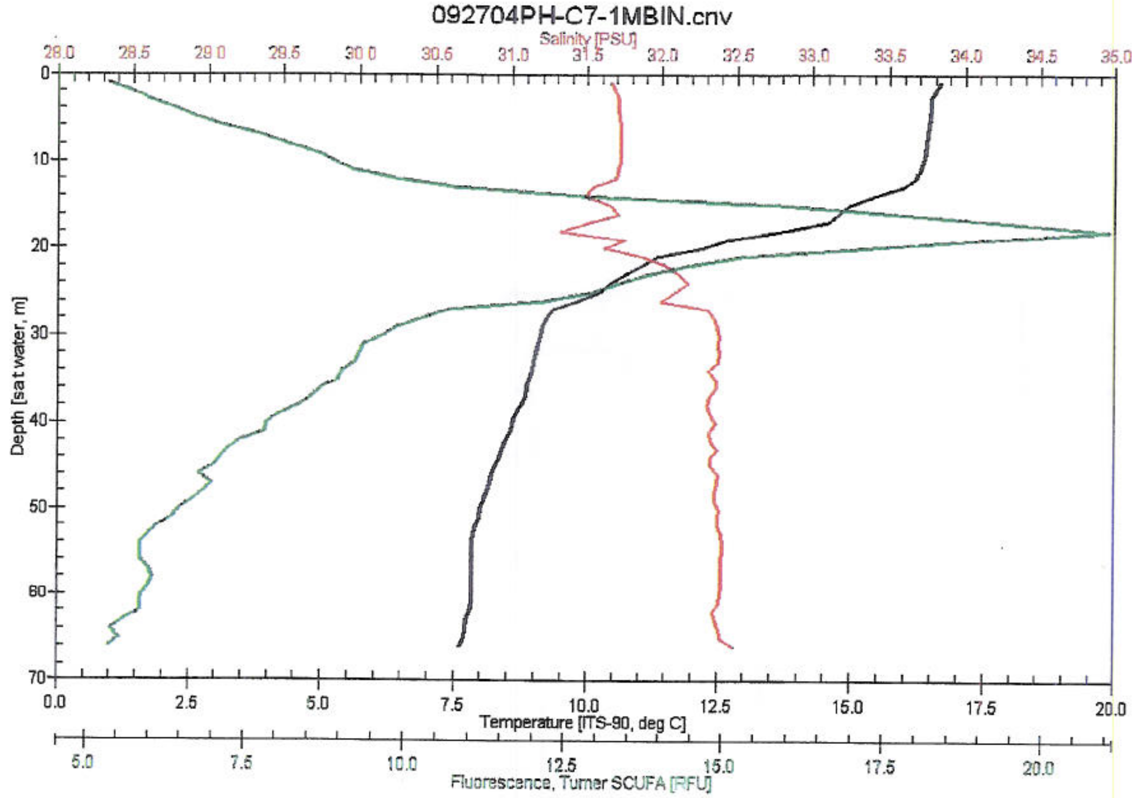

080304PH-C4-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0


080404PH-C2-1MBIN.cnv
Oxygen, Beckman/YSI [mg/l]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
Temperature [ITS-90, deg C]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0

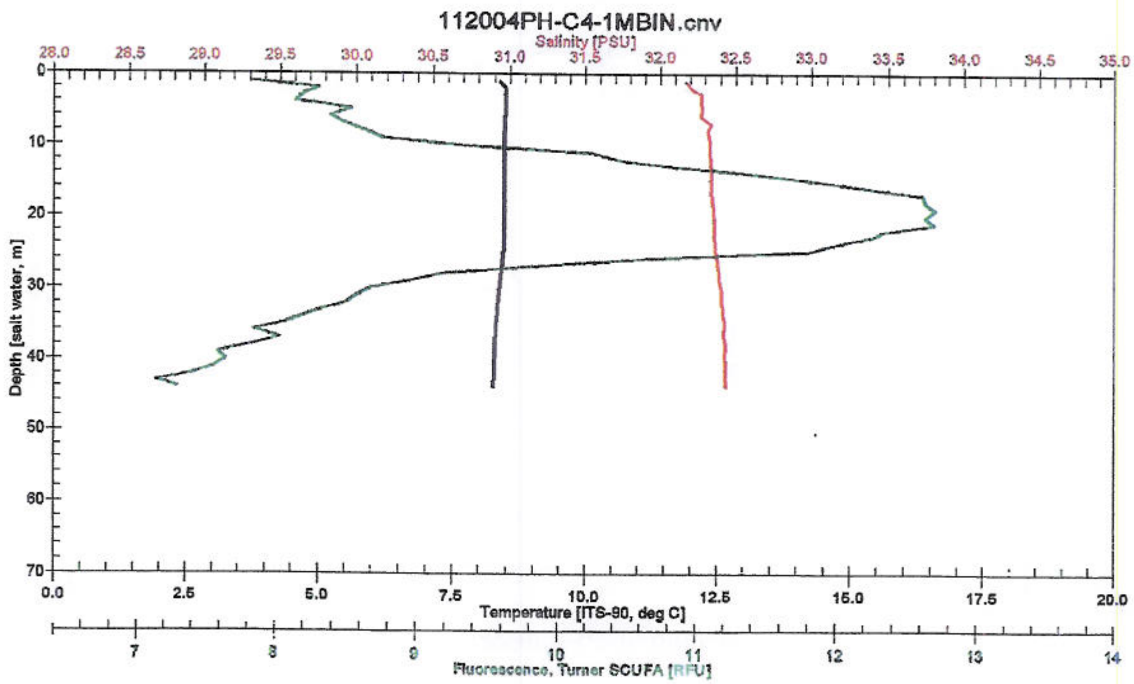
Pigeon Hills September

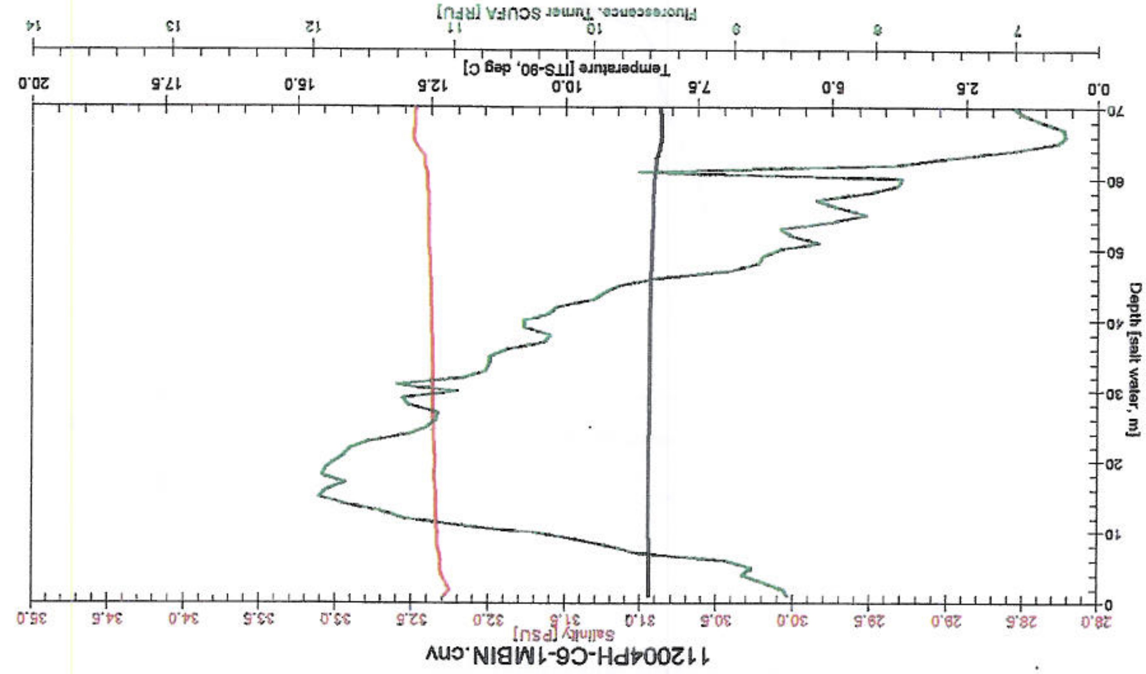


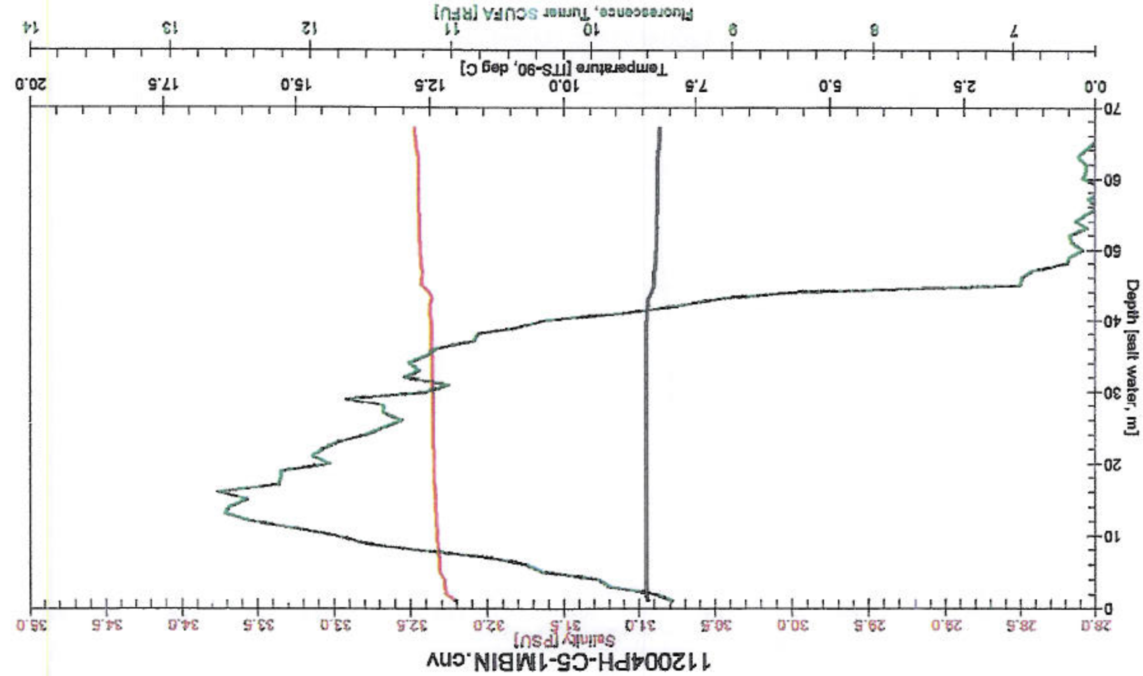


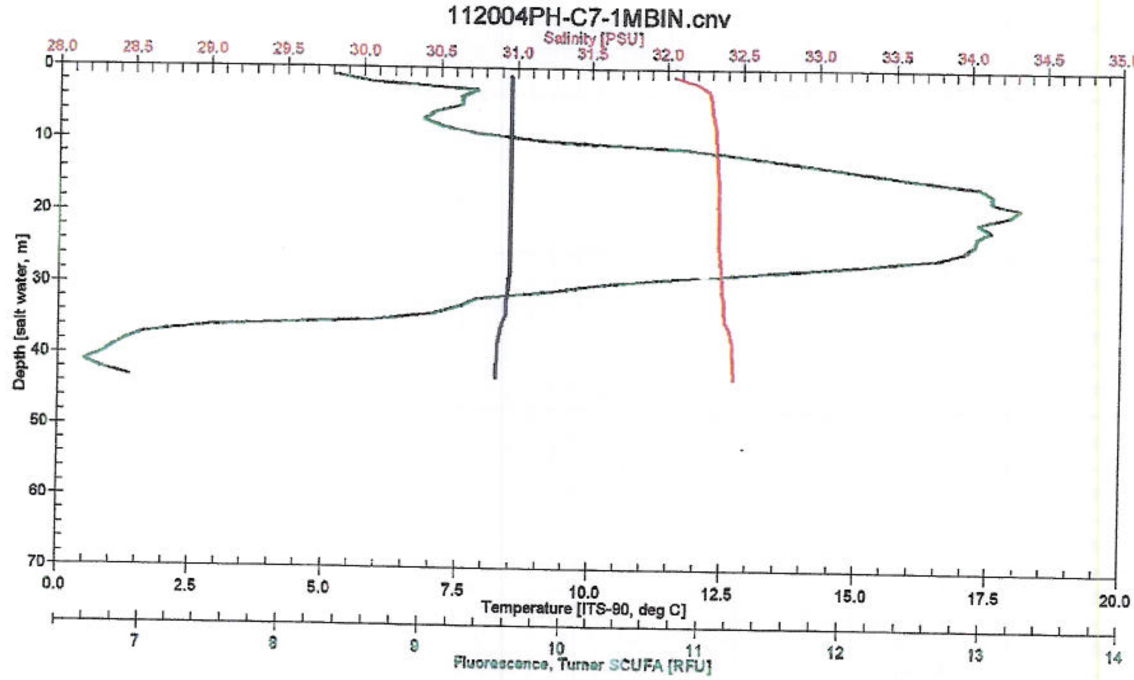


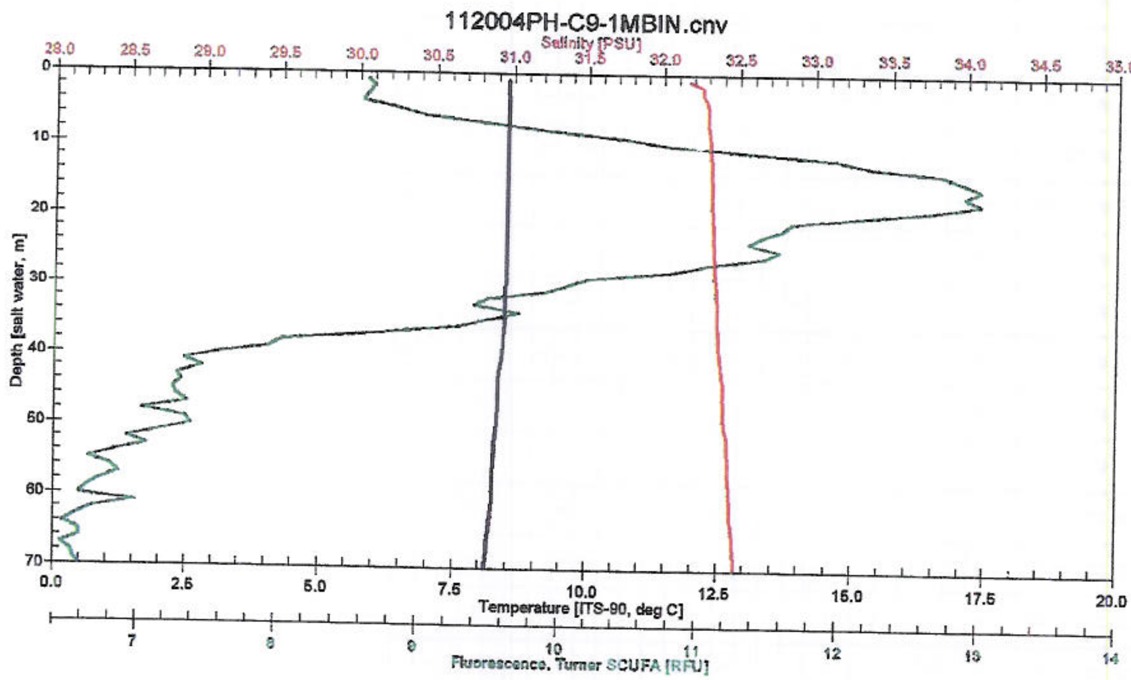
Pigeon Hills November 2004




112004PH-C6-1MBIN.cnv
Salinity [PSU]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]
Depth [salt water, m]


112004PH-C5-1MBIN.cnv
Salinity [PSU]
Temperature [ITS-90, deg C]
Fluorescence, Turner SCUFA [RFU]
Depth [salt water, m]


112004PH-C7-1MBIN.cnv
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Temperature [ITS-90, deg C]
7
8
9
10
11
12
13
14
Fluorescence, Turner SCUFA [RFU]


112004PH-C9-1MBIN.cnv
Salinity [PSU]
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
33.0
33.5
34.0
34.5
35.0
Depth [salt water, m]
0
10
20
30
40
50
60
70
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Temperature [ITS-90, deg C]
7
8
9
10
11
12
13
14
Fluorescence, Turner SCUFA [RFU]

APPENDIX E BENTHIC INFAUNAL REPLICATE RESULTS
STELLWAGEN/LONG BANK AND MUD HOLE

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Protozoa																												
Sarcodina		3	10																									13
Cnidaria																												
Athenaria																										1		1
Ceriantharia spp.														1										1	1			3
Edwardsia elegans							1	7	2					1	1				4	3	1	1	2	3				26
Nemertea																												
Nemertea spp.					1		1			3	1	1	2		3	3		1		4	1			1	1			23
Nemertea A							1					2	2		1								1				2	9
Nemertea D					2															1								3
Nemertea E	3	1	2			2			1			1			2	5	3		3			1	1		1			26
Nemertea F					2													2										4
Amphiporus caecus	6	1	1	2	2		1		2		1	3		1					1					1	1	3		26
Amphiporus crenuatus			1																									1
Carinomella lactea						1		1	3	3	4		3	1	5	3	6		1	4	3						1	39
Cerebratulus lacteus																			1				1				1	3
Micrura sp. A		1	4		5						1		1	4	2	1					1				2			22
Micrura sp. C	10	4	1	9	3	9	1	1	3	1	2	1		4	4	7	4	9	3	7	1	3	4	11	2	5	3	112
Micrura rubra									1			1	3	1		1				1		1				1		10
Tetrastemma sp.		1																				1						2
Phoronida																												
Phoronis architecta	7	6	7	11	9	10		2	2			1	3	2		13	3	5	15	2	5	8	6	1	3	4	3	128
Oligochaeta																												
Polygordius spp.	4	2	3																									9
Tubificoides intermedius							1	4	6	5	6	3	4	7	4				6		3							49

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Ampharetidae																												
Ampharetidae spp. (juv.)	6	2	3	3	2	8									3						2							29
Ampharete acutifrons	1			1		1																						3
Ampharete balthica	8	4	6		1	2																						21
Ampharete finmarchica					2																					1		3
Ampharete spp. (juv.)											6																	6
Anobothrus gracilis	12	4	11	3	9	7	267	116	181	73	57	33	85	69	75	31	36	72	217	338	128	234	187	208	55	69	43	2620
Asabellides oculata	1														1										1	2		5
Melinna cristata							1	1		2										1	1							6
Amphinomidae																												
Paramphinome pulchella																1												1
Aphroditidae																												
Aphroditidae																	2											2
Apistobranchidae																												
Apistobranchus sp.						1																						1
Apistobranchus tulbergi								1																				1
Apistobranchus typicus	2	2	5	1	1																							11
Arabellidae																												
Arabellidae																										1		1
Drilonereis longa													1															1
Capitellidae																												
Capitella spp.	7	3	2	6	1	3					1							3				1						27
Heteromastus filiformis							1	5	5			7	1			4			1	1	1	1						27
Mediomastus californiensis	19	33	21	28	35	41	7	10	17	15	15	11	9	11	17	13	13	12	27	3	9	15	36	15	19	17	13	481

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Cirratulidae																												
Cirratulidae spp.														2														2
Aphelochaeta 7.30										4			4		4	1					4	2						19
Aphelochaeta marioni	24	24	17	19	16	33	10	18	5	5	8	14	22	24	44	8	7	11	8	8	3	4	10	11	20	16	19	408
Chaetozone setosa	2	3	3	2	8	11	2	11	10	13	10	34	31	35	47	27	24	44	7	12	10	10	9	10	7	11	3	396
Monticellina baptistae					11			2																				13
Monticellina dorsobranchialis	1										1	1																3
Tharyx acutus	37	46	29	44	40	20		1		1	3				2	1	1										1	226
Cossuridae																												
Cossura longocirrata		1		1	1	4	9	9	15	14	12	13	14	32	11	17	11	9	3		2		4		1			183
Dorvilleidae																												
Dorvilleidae spp.											1																	1
Parougia caeca	1	1	1		2	3	1						1		1		1	1										13
Flabelligeridae																												
Brada sp.									1																			1
Brada villosa																					1	5			1			7
Diplocirrus hirsutus				1		1		2	1				4			4	2	1	6	4	7	2	2	5	2	5	2	51
Glyceridae																												
Glyceridae spp. (juv.)																							1					1
Glycera capitata																											1	1
Goniadidae																												
Goniada maculata	3	3	7	6	3	7	2							2	1	1		1	1	3	2	2	6	2			1	53
Hesionidae																												
Microphthalmus aberrans					1																							1

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Lumbrineridae																												
Lumbrineridae spp. (juv.)				6						1						1								9				17
Ninoe nigripes	37	29	27	43	36	61	22	14	14	40	22	45	20	31	56	27	27	30	38	10	37	9	27	14	27	20	39	802
Scoletoma sp.																		1										1
Scoletoma fragilis	4	1	5		3	5	4	6	11	1	2	8	4	1	4	2	3	2	5	10	7	6	7		7	6	9	123
Scoletoma tenuis														1														1
Maldanidae																												
Maldanidae spp. (frag.)							2	3				1									1							7
Axiothella rubrocincta											1		1												1			3
Euclymene zonalis																								1				1
Euclymeninae sp. A		1			1		35	27	51	1	4	1	36	25	30	14	18	22	18	16	37	7		1	6	1	6	358
Maldane sarsi	5	6	2	1	1	4	123	65	105	18	30	3	22	6	15	4	6	7	42	9	27	30	35	37	11	3	17	634
Praxillella gracilis													1															1
Praxillella praetermissa							7	3	4						2	1	3	2	7	1	2	1	5	5	1	1	3	48
Praxillura ornata	1	2	1	1	7	2	4		1			1	1		3			1		1						2	1	29
Nephtyidae																												
Nephtyidae sp. (juv.)	10	8	17	16	5	4	2	1		8	3	1	5		1				1	1		2	2	3	4	4	2	100
Aglaophamus circinata	1		2				1															1						5
Aglaophamus neotenus		3															4											7
Nephtys caeca	5																											5
Nephtys ciliata							1																	1				2
Nephtys incisa	2			4	8	25	3	3	1	2		11	3	3	5	3	5	8	3	4	8	3		4	6	5	5	124
Nephtys spp.			1							2																		3
Nereidae																												
Nereis grayi	5	6	5	11	4	8	7	2	6	1	1	2		1	2	5	3	2	5	2	4	6	15	8	16	14	14	155
Opheliidae																												
Ophelina acuminata	6	9	13	1	3				1										2		1	1	3		4	3	4	51

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Orbiniidae																												
Leitoscoloplos acutus	12	16	10	7	8	24		2	3	2	2	9	8	8	8	14	8	18	13	5	7	5	8	6		1	5	209
Scoloplos armiger	7	4	9	4	4														1							1		30
Oweniidae																												
Galathowenia oculata	3		3	4	8	2	16	9	16	7	6	5	20	11	29	41	21	39	51	26	66	14	20	21	7	13	7	465
Myriochele heeri			4		2		3	4	1		2		10		1	20	8	13	3	9	3	3	2	4	2	3	1	98
Owenia fusiformis	3	11	8	1	1	2	1						4			3	1	2					1					38
Paraonidae																												
Aricidea catherinae	4	12	20	11	13	15																						75
Aricidea quadrilobata	7	6	5	23	14	11	38	15	33	27	49	69	35	19	34	37	33	40	39	35	26	7	9	10	8	11	9	649
Levinsenia gracilis	12	12	14	25	54	46	70	45	71	81	66	104	35	18	55	18	27	12	38	4	24	41	54	43	40	29	53	1091
Pectinariidae																												
Pectinaria gouldii	4	9	3	6		1																						23
Phyllodocidae																												
Eteone flava	1	3				1											2		1				1	1	1			11
Eteone longa	19	11	12	18	9	16	10	1	3	5	6	13	10	4	17	14	12	12	14	11	11	9	12	9	4	14	5	281
Paranaitus speciosa	1		1		1																							3
Phyllodoce sp.								1																				1
Phyllodoce mucosa	5	2		3			1		1				1						3		1	1			2			20
Polynoidae																												
Bylgides sarsi																			1									1
Gattyana cirrosa									2					2		2		1		2	1	2	1	1	1		2	17
Harmothoe iextenuata								1																				1
Hartmania moorei																			1									1
Sabellidae																												
Chone spp.	1																					1						2
Euchone incolor	1																											1
Laonome kroeyeri			4																	1			1					6

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Scalibregmidae																												
Scalibregma inflatum	1	2	1	1	1		2									1		4	1	4			1	3	5	13	1	41
Sigalionidae																												
Pholoe minuta	10	9	10	14	10	4	3	2	2	5	1	2			2	7	3	4	8	7	4		3	4	1	2		117
Sphaerodoridae																												
Sphaerodoridium sp. A	3	1	2	1	1	1	1												2					1		2	1	16
Spionidae																												
Dipolydora socialis	2	8	5	1	2		1		1		1					1	1	2	10	1	9	11	7	3	7	2	1	76
Laonice cirrata						1		1				1										2						5
Prionospio steenstrupi	201	191	186	305	197	175	127	41	104	48	55	88	56	31	59	137	104	148	129	105	79	81	205	160	135	203	250	3600
Spio limicola	244	232	150	185	154	242	30	61	138	112	118	206	187	212	332	359	312	402	580	285	293	195	348	241	366	352	184	6520
Spio thulini	1																											1
Spiophanes bombyx	4	1	2	1			1																					9
Spiophanes kroeyeri								1	2		1											1						5
Sternaspidae																												
Sternaspis scutata		1	2	1		1			2		1	1	3		1		1			1					1		2	18
Syllidae																												
Syllidae spp.										1																		1
Exogone hebes	16	9	7	7	10	5	5							1			3		2	2	2	1	2	3	2	2	4	83
Exogone longicirris														2														2
Exogone verugera	11	8	9	10	9	8	14	23	26	10	5	2	20	12	29	21	9	9	11	6		1	5	6	2	7	7	280
Syllis cornuta				1																						1		2
Syllides japonica												2	3			2				5					1			13
Syllides longicirrata									2							4	2	1	1									10

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Terebellidae																												
Nicolea zostericola											1																	1
Polycirrus c.f. norvegicus		1			4	2	2		1						1	1			6	3	3	4	2	2	1	1	2	36
Pista cristata							1	2	1																1			5
Proclea graffi												1													1			2
Terebellidae											1																	1
Terebellidae spp.				3																								3
Thelapus setosus									2																			2
Trichobranchidae																												
Terebellides atlantis	1	3		6	9		2	1	6	8	2	8				2	5	1	5	13	6	5	6	10	5	7	7	118
Terebellides stroemi								1											1									2
Trichobranchus roseus									1	2	1		2	1	3	5		1		1	2			1		1		21
Trochochaetidae																												
Trochochaeta multisetosa	2		1	1		2										2				1						2		11
Sipuncula																												
Sipuncula sp. A		1									1		2	1				4										9
Phascolion strombi		2		1		1	1	3	1				1		1			2	1	3	3	6	5	1			2	34
Cumacea																												
Campylaspis rubicunda					1			1						1				1							2			6
Campylaspis affinis	1			1							1						1	1	1	1				4			2	13
Campylaspis sp.																							1					1
Diastylis quadrispinosa																									1			1
Diastylis spp.		1	1		1			1					1					2	1			1		2				11
Eudorella pusilla	3	7	1				2	3	1	3	1		1	1	1	1	3	5	1	3	1	1		2	1	6		48
Eudorella truncatula										1				1				1										3
Petalosarsia declivis			1	1			1																1					4

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Isopoda																												
Edotea montosa	59	26	14	4		1						1	2					1					1		1	2	1	113
Pleurogonium rubicundum																						2						2
Ptilanthura tenuis	2	2	12	1		2		1					1															21
Amphipoda																												
Aeginina longicornis						2																						2
Ameroculodes sp. A																		1										1
Ampelisca macrocephala			2					2										1					4		2		1	12
Anonyx liljeborgi	1		1															2	1			2			1	1		9
Argissa hamatipes	1		1					1		1								2		1			1			2		10
Byblis gaimardi									1		1			1	1					1								5
Bathymedon obtusifrons							2	1	4	1	1		2	1		4	2	6				1		1		1		27
Casco bigelowi									1											1				1	1		3	7
Deflexiloides intermedius		1		1																		1						3
Erichthonius fasciatus											1																	1
Haploops fundiensis							2	2	5				1			1	2	3	1		1		2			1	1	22
Harpinia propinqua	4	5	1	1		6	5	6	7		4			2		7	2	5	2	3		4	2	3	9	12	9	99
Hippomedon propinquus		1	1	1	1		1	2		1	1							1	5						4	2		21
Leptocheirus pinguis									1													1					1	3
Metopella angusta	6		1	1			1	2	1				1				1	2	8	5		1	1	3		3		37
Orchomenella minuta																						2	1				1	4
Parathemisto compressa																1		1										2
Photis pollex				1			1	1						1						1				1				6
Proboloides holmsi																					1							1
Protomedeia fasciata																									1			1
Stenopleustes inermis				2			1										1	1	1			2						8
Unciola irrorata									1													1						2
Unciola sp.																									1			1

ORGANISMS	MH2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Mysidacea																												
Erythrops erythropthalma																				1								1
Decopoda																												
Crangon septemspinosa					1																1							2
Aplacophora																												
Chaetoderma nitidulum					1				1					2	1	1									2	1	1	10
Bivalvia																												
Bivalva		1																										1
Arctica islandica	16	4	20											1													1	42
Astarte undata	3	1	11	3			2	1							1					3	2		2	1	1		2	33
Cyclocardia borealis							2																		1			3
Cerastoderma pinnulatum	2	3	4																									9
Crenella decussata	2		1	2	2	4	11	1	6	4	1	3	2		10			7	22	37	18	16	16	22	10	10	11	218
Crenella glandula							1																					1
Cyclocardita borealis						1																						1
Hiatella arctica		1																										1
Mactridae	1			1																								2
Mya arenaria	1		5												1						1							8
Mytidae spp. (juv.)			1																									1
Nucula delphinodonta	71	33	91	9		8	14	6	10	2	3	3	18	12	8	11	9	26	24	35	15	11	34	56	13	23	23	568
Ennucula tenuis			1			1	4		3				2	2	7	1		5	1	5		2	1	4	2	1		42
Nuculana minuta																					1							1
Periploma papyratum				3		2	6	3	8	5	4	3	6	7	11	12	5	5	14	8	16	8	10	16	5	9	12	178
Thyasira gouldii	23	8	21	42	25	19	26	21	29	1	15	3	18	4	19	23	25	26	45	35	25	27	23	31	30	20	64	648
Yoldiella lucida	1	2	2	6	3	5		4	3		3	4	1	1	1	1	3	5	8	3	4		4	6	2	4	2	78

ORGANISMS	MHB2B-1	MH2B-2	MH2B-3	MH4B-1	MH4B-2	MH4B-3	SB1-1	SB1-2	SB1-3	SB2-1	SB2-2	SB2-3	SB3-1	SB3-2	SB3-3	SB4-1	SB4-2	SB4-3	SB5-1	SB5-2	SB5-3	SB6-1	SB6-2	SB6-3	SB7-1	SB7-2	SB7-3	Total
Gastropoda																												
Gastropod egg cases							1		3								3	5					2			3	4	21
Colus spp.																										1		1
Cylichna alba								3			1							1			1	1	2	4	2		2	17
Frigidalvania pelagia							2	3	2	1	2	1	1	3		1	2	7	4	2	3	1	2	2	3	4	1	47
Haminoea solitaria								2																				2
Moelleria costulata																											1	1
Neptunea despecta tornata															2												1	3
Neverita duplicata		1																										1
Oenopota sp.					1																		1		1			3
Oenopota cancellatus							2	2					1	1	1		1			1						5		14
Scaphopoda																												
Dentalium entale	2	1	2				1	2	2	1			1			3	1	4	3	2	1		1	2	1		2	32
Echinodermata																												
Asterias sp																1												1
Asterias forbesi																									1			1
Asteroidea spp.							2																					2
Ctenodiscus crispata										2			1			1			3	1		2		3				13
Echinarachnius parma	5	1	16	3															1									26
Ophiura sarsi				1			3																					4
Ophiuroidea (juv.)		1					1		1										4						1	1	1	10
Ascidacea																												
Ascidacea																									1			1
Mogula sp																							3					3
Total No. Individuals	1010	865	886	944	772	884	940	600	958	544	550	728	740	628	982	958	796	1088	1497	1125	940	834	1172	1046	893	974	883	24236
Total No. Taxa	74	72	74	67	60	56	71	66	67	45	55	45	59	52	55	61	53	68	69	66	60	65	63	61	73	64	64	204

APPENDIX F. LIST OF PARTICPATING FISHERMEN

Joe Arsenault Jnr.	charter boat/line
Tom Bell	gillnet
Hugh Bishop	line/lobster
Frank Colati	line
Robert Fisher	trawler
Ron Gustafson	trawler
Bill Lee	trawler
Dave LeRosa	line/lobster
Frank Mirachi	trawler
Owen Toland	line
Robert MacKinnon	gillnet
Tim McDonald	trawler
Sam Novello	trawler
John Shea	trawler
Russell Sherman	trawler
Richard Taylor	scallop/line
Jan Waalewyn	line
Rob Yeomans	charter boat/line
Bob Yeomans	charter boat/line