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PHOEL ASSOCIATES, INC.

FINAL REPORT FOR THE PROJECT:

A. A Quantitative Assessment of Substrate Changes Due to Scallop Dredging in the New York Bight and Associated Recovery Rates

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B. Abstract

Side scan sonar images and drop camera videotapes were accomplished along a one nautical mile experimental transect which was dredged by a commercial scallop vessel and on a one nautical mile control transect where no dredging was performed. Both the side scan images and the drop camera videotapes indicated seabed differences before and after dredging on the experimental transect and no changes on the control transect. After three months (Cruise 1 in April – Cruise 2 in August) the experimental transect was indistinguishable from either the control transect or the pre-dredge experimental transect. Dredging was not accomplished on cruise 2 as it was not determined that the transect had returned to pre-dredge conditions until the side scan images and drop camera videotapes were analyzed after the cruise. This experiment

was repeated for a six-week period between observations (Cruise 3 in November – Cruise 4 in December). This shorter time interval resulted in the experimental transect being recovered just about to its pre-dredge condition. Biological samples were obtained by dredging on cruises 1, 3, and 4. Standard biomass (kg) was compared between each cruise and the biological data were analyzed for species diversity and dominant species using the Shannon-Weaver Index (H'). Sand dollars (*Echinarachnius parma*) were the dominant species on cruise 1 and to a much lesser extent on cruise 4. Cruise three had no dominant species. When the biomass of the sand dollars was removed from the total biomass of each cruise there was no significant differences between the cruises quantitatively indicating that in both experiments the experimental transect had recovered to its pre-dredge condition. Grain size analyses are still ongoing.

C. Executive Summary:

This project addressed the specific research activity "Conduct investigations that promote a better understanding of the effects of repeated deployment of mobile bottom-tending fishing gear across various habitat types." which was identified and discussed at the CRPI/NEFMC workshops and scooping meetings in Maine and Massachusetts.

The goals of this project were to visually and quantitatively assess the differences between depletion tows (to the removal of at least 95% of the scallops from the substrate) and the control transect substrate and to visually and quantitatively document the rate of recovery of the dredged transect, in comparison with the control transect.

The objectives were to provide visual and quantitative data to fishery managers, the fishing industry, and the environmental community, so that the scallop dredging impacts on a rock, gravel and sand substrate, as well as the associated recovery rates will be known. This information was disseminated in this final report, a peer-reviewed paper, an oral presentation, and is available to the popular literature. The results of this project should aid in assisting consensus among the above stakeholders.

The proposed study area for this project is centered at 40° 07' N, 073° 53' W, in 22-24 m of water, approximately 15 km. offshore of Manasquan Inlet, NJ. This area was chosen because it has historically been fished for scallops and its bottom has been categorized as rocks of various sizes on a gravel and sand substrate with a seasonal abundance of surf clam valves. The bottom in this area supports numerous species of fish and shellfish in various life stages. Four research cruises were accomplished in 2004, i.e. April, August, November, and December. The original project design was to sample every three months over a 12-month period beginning in April 2004. However, because the substrate had returned to background levels by August 2004 (as determined by the side scan sonar and drop video camera), the project's design was changed to conduct a duplicate experiment in the late fall (November-December) of 2004.

Side scan sonar and a drop video camera system were used on a one nautical mile (nm) long control transect to document the substrate and benthos without dredging and on a one nautical mile long experimental transect to document the substrate and benthos before and after extensive dredging to simulate a heavily fished area. Over both transects the drop video camera documentation occurred at five discreet intervals (sampling stations) equidistant along the transect (0.25nm apart) whereas the side scan sonar data acquisition was continuous over each transect. The experimental transect was dredged on cruises 1, 3, and 4. After three months (Cruise 1 in April – Cruise 2 in July) the experimental transect was indistinguishable from either the control transect or the pre-dredge experimental transect. Dredging was not accomplished on cruise 2 as it was not determined that the transect had returned to pre-dredge conditions until the

side scan images and drop camera videotapes were analyzed after the cruise. This experiment was repeated for a six-week period between observations (Cruise 3 in November – Cruise 4 in December). Benthic samples were obtained from the experimental transect using the vessel's two 15 foot commercial scallop dredges. To attain at least 95% depletion four tows were made over the transect using precision navigation and the side scan sonar to ensure that at least 80%-90% of the transect was dredged. When each tow was complete the dredges were brought aboard and dumped on deck. The piles from each dredge were kept separate and hand sorted down to the lowest taxonomic level possible (usually genus or species). A total count and weight were obtained for each taxon. For some species, e.g. sand dollars, skates, sea stars, with very high abundances, sub-samples were used to estimate total counts and weights.

At most of the drop video camera stations a bottom grab was conducted to obtain sediment samples for grain size analyses. It is anticipated that there will be differences in the grain size characteristics from the pre-dredge and post-dredge samples. Because these analyses were a non-funded addition to the project these analyses are still on going.

The first experiment was initiated on 6 April 2004 and completed on 2-3 August 2004. During the intervening period of 118 days the area was undisturbed except for natural oceanographic and meteorological influences. In the area of the experiment April can be considered as a transition month where the rough conditions of winter give way to the more benign conditions of summer. Both the side scan sonar images and drop camera videotapes documented the effects of dredging immediately after dredging occurred and the return of the sediments and fauna to pre-dredge conditions when resurveyed after 118 days.

The second experiment took place between 4-5 November 2004 and 21-22 December 2004, a period of 47 days. Like April, November can be considered a transitional month for the area in which the experiment was conducted. However unlike April, November is when meteorological and oceanographic conditions transition from low energy in the summer to high energy in the winter. Due to the high-energy environment the dredge tracks created and observed in November were barely discernable in the side scan sonar images or drop camera videotapes in December, only 47 days later.

The Shannon-weaver index (H') was used to assess species diversity within the experimental transects benthic community. The diversity index was calculated using natural logs to obtain a unit free entropy number. In both experiments by far the dominant invertebrate, by weight and numbers, was the sand dollar ((*Echinarachnius parma*), especially on cruise 1 and to a much lesser extent on cruise 4. Cruise three had no dominant species. When the biomass of the sand dollars was removed from the total biomass of each cruise there was no significant differences between the cruises quantitatively, indicating that in both experiments the experimental transect had recovered to its pre-dredge condition.

The results of this project have been presented at the Marine Technology Society's OCEAN 2005 Conference "One Ocean", 18-23 Sept. 2005 in Washington, D. C. and the paper "Scallop Dredging in the New York Bight: Substrate Changes and Associated Recovery Rates" has been published in The Proceedings of the OCEANS 2005 MTS/IEEE Conference and Exhibition, Washington, D. C.

D. Purpose:

1. The sea scallop (*Placopecten magellanicus*) fishery in the US EEZ of the northwest Atlantic Ocean is one of the most valuable fisheries in the northeastern United States. This scallop fishery faces several challenges, one of which is the possible loss of areas where dredging is permitted. Historically, the reasons for such area closures arose from resources being overfished and populations at low overall levels of abundance. Thus, scallop sanctuaries were required in order to rebuild the populations. These areas were either directed toward scallop protection, e.g. Mid-Atlantic closed area, or the protection was a result of closures to protect demersal fish stocks, e.g. Georges Banks closed areas. Recently another reason to close areas to scallop dredging and bottom trawling has been discussed in the peer-reviewed literature as well as the popular press. These potential closed areas are not for the protection of the scallops or demersal fish but for the protection of the habitat, especially essential fish habitat (EFH). In such cases mobile fishing gear may quite possibly be banned from the area. By the closing of areas considered to be EFH to the scallop fishery, additional fishing effort would be directed upon those areas remaining open to mobile gear thus putting more pressure on those resources being fished, as well as the fishing industry itself. It is therefore important to quantitatively assess the effects of scallop dredging on various substrates to determine its immediate impact on the substrate and associated benthos, as well as the rate of recovery. Hard bottom, i.e. rock and gravel, are generally considered to be more productive areas for fishery resources than softer bottoms, i.e. muds and sands. However muds and sands appear to be more resilient after dredging or trawling has occurred. This study therefore took place in an area of rocks, gravel, and sand. Previous scallop dredging indicated the presence of rocks of varying sizes. We anticipated that physical damage to the substrate would be directly related to fishing effort.

2. This project addresses the specific research activity "Conduct investigations that promote a better understanding of the effects of repeated deployment of mobile bottom-tending fishing gear across various habitat types." which was identified and discussed at the CRPI/NEFMC workshops/scooping meetings in Maine and Massachusetts.

The first goal of this project was to visually and quantitatively assess the differences between depletion tows (to the removal of at least 95% of the scallops from the substrate) and the control transect substrate.

The second goal was to visually and quantitatively document the rate of recovery of the dredged transect (in comparison with the control transect) over a one-year period.

The objectives were to provide visual and quantitative data to fishery managers, the fishing industry, and the environmental community, so that the scallop dredging impacts on a gravel and sand substrate as well as the associated recovery rates will be known. This information will be disseminated in a final report, a peer-reviewed paper, an oral presentation, and in the popular literature. The results of this project should aid in assisting consensus between the above stakeholders.

E. Approach:

1. Work Performed and Methodology

Overview

The proposed study area for this project is centered at 40° 07' N, 073° 53' W, in 22-24 m of water, approximately 15 km. offshore of Manasquan Inlet, NJ. This area was chosen because it has historically been fished for scallops and its bottom has been categorized as rocks of various sizes on a gravel and sand substrate with a seasonal abundance of surf clam valves. The bottom in this area supports numerous species of fish and shellfish in various life stages. Because of the hard rocky bottom scallopers usually avoid the area if scallops in commercial numbers can be caught elsewhere in areas easier to dredge. In 2004 there was no fishing pressure from scallopers in the area because scallops had been abundant elsewhere (Personal Communication, Captain K. Ochse F/V CHRISTIAN AND ALEXA). Large demersal trawlers also avoid the area because of the limited abundance of commercially important adult fish and the smaller local trawlers avoid the area due to its rough bottom. Because both types of mobile ground gear, i.e. dredges and trawls, avoid the area, we were confident that mobile gear would not interfere with our test transects by altering the bottom after the experiment had started. Fixed gear such as pots and traps posed no interference.

Four research cruises were accomplished in April, August, November, and December of 2004. The original project design was to sample every three months over a 12-month period beginning in April 2004. However, because the substrate had returned to background levels by August 2004 (as determined by the side scan sonar and drop video camera), the project's design was changed to conduct a duplicate experiment in the late fall (November-December) of 2004.

Side scan sonar and a drop video camera system were used on a one nautical mile (nm) long control transect to document the substrate and benthos without dredging and on a one nautical mile long experimental transect to document the substrate and benthos before and after extensive dredging to simulate a heavily fished area. Over both transects the drop video camera documentation occurred at five discreet intervals (sampling stations) equidistant along the transect (0.25nm apart) whereas the side scan sonar data acquisition was continuous. The experimental transect was dredged on cruises 1, 3, and 4. After three months (Cruise 1 in April – Cruise 2 in July) the experimental transect was indistinguishable from either the control transect or the pre-dredge experimental transect. Dredging was not accomplished on cruise 2 as it was not determined that the transect had returned to pre-dredge conditions until the side scan images and drop camera videos were analyzed after the cruise. This experiment was redone for a six-week period between observations (Cruise 3 in October – Cruise 4 in December). At each drop video station a bottom grab was used before and after dredging to obtain sediment samples for grain size analyses.

Navigation and Side Scan Sonar

Side scan sonar was utilized to examine the seabed prior to and after every sampling. The sonar allowed investigators to determine if the bottom had been disturbed prior to the original surveys, what areas had been covered or missed during the field sampling, and determine the presence of previous sampling dredge scours, if any.

Prior to the commencement of, and after each field sampling session, a detailed side scan sonar survey of the research and control areas was completed. The survey utilized a Klein dual frequency (100 and 500kHz) digital side scan sonar. The 500kHz provided better imagery and was utilized for all comparisons. The sonar system was integrated with a Trimble DMS 212 GPS. The Trimble provided real-time differential positions with sub-meter accuracy and a 1Hz up-date rate.

To insure the best sonar coverage of the experimental and control transects, the sonar survey was conducted with an offset of approximately 20 to 25m. The offset insured the area of low resolution directly under the towfish was outside the actual area of interest. Repetitive surveys were conducted at both 50 and 75m ranges optimizing the range and resolution. Interfacing the GPS with a survey computer operating the HYPACK survey software assisted ships navigation. The software allowed the display of the ship's position, survey tracks, and research areas in real time. In this manner the captain and researchers always understood the relative positions of the vessel and research areas. Sonar and navigation data were recorded and saved to the sonar computer. Real-time sonar coverage was displayed along with the research area boundaries so as to insure proper coverage during the sonar survey. The 20-meter wide experimental transect was dredged to approximately 80 to 90 percent. The scallop dredges had missed several small areas approximately 1 to 3 meters wide.

During dredging operations the ship's position was continuously documented at 1-second intervals via the HYPACK survey software. Positions were also recorded during camera drops. Target areas were visually displayed when reoccupying camera locations. This allowed exact positioning of the vessel during camera drops. Analyses of the side scan sonar data was accomplished ashore by the sub-contractor.

Drop Video Camera System

The drop video camera system consisted of a Sony digital video camera mounted on a four-legged stand so that the bottom area covered by the camera was always the same from drop to drop (0.18 m^2). The scallop vessel was maneuvered into position using the HYPACK survey software and the two scallop dredges were dropped underfoot to anchor the vessel. The video camera was hard wired to a video monitor aboard the scallop vessel so that all drops were monitored in real time. The camera was hand lowered to the bottom on a line through a block on a davit. A battery-powered diver's light was used for illumination in association with ambient light, which was variable depending upon tidal current and weather conditions. After several minutes of videotape the camera was raised about a meter off the bottom and repositioned. Thus there were five video sub-sites at each of the five stations along each transect. The video camera tapes were duplicated and analyzed ashore by the P. I. and video camera sub-contractor.

Biological Samples and Analyses

The study site contained two treatments, a control transect and an experimental transect that were each one nautical mile long and ran parallel in an east to west fashion. Samples for the biological component of the study were collected from three of the four cruises: cruises 1, 3, and 4. The benthic samples were obtained from the experimental transect using the vessel's two 15-foot commercial scallop dredges. To attain at least 95% depletion four tows were made over the transect using precision navigation and the side scan sonar to ensure that 80%-90% of the transect was dredged. Two tows were made from east to west and two from west to east to avoid directional bias. The dredges were deployed over each side of the vessel, making the dredged area 18.0 m wide. Each transect encompassed 8280m^2. The tows were made at approximately 4.5 knots and the average bottom time per tow was 16.7 minutes. When each tow was complete the dredges were brought aboard and dumped on deck. The piles from each dredge were kept

separate and hand sorted down to the lowest taxonomic level possible (usually genus or species). A total count and weight were obtained for each taxon. For some species, e.g. sand dollars, skates, sea stars, with very high abundances, sub-samples were used to estimate total counts and weights.

Grain Size Analyses

At most of the drop video camera stations a bottom grab was conducted to obtain sediment samples for grain size analyses. It is anticipated that there will be differences in the grain size characteristics from the pre-dredge and post-dredge samples. Because these analyses were a non-funded addition these analyses are still on going.

2. Project Management

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F. Findings:

1. Accomplishments and Findings

The first experiment was initiated on 6 April 2004 and completed on 2-3 August 2004. During the intervening period of 118 days the area was undisturbed except for natural oceanographic and meteorological influences. In the area of the experiment April can be considered as a transition month where the rough conditions of winter give way to the more benign conditions of summer.

Initial side scan sonar data indicated a natural bottom on both the experimental and control transects. Natural patterns of sand waves were clearly evident and undisturbed (Fig. 1). There was no evidence of previous fishing activity as could be detected by the side scan sonar imagery. The effects of the winter season can be recognized in the right side of Fig. 1, as pronounced sand waves are evident. This was the condition of the substrate before dredging was accomplished. On the left side of Fig.1 the tracks of the dredges are obvious. They have effectively created shallow furrows and flattened the sand waves.

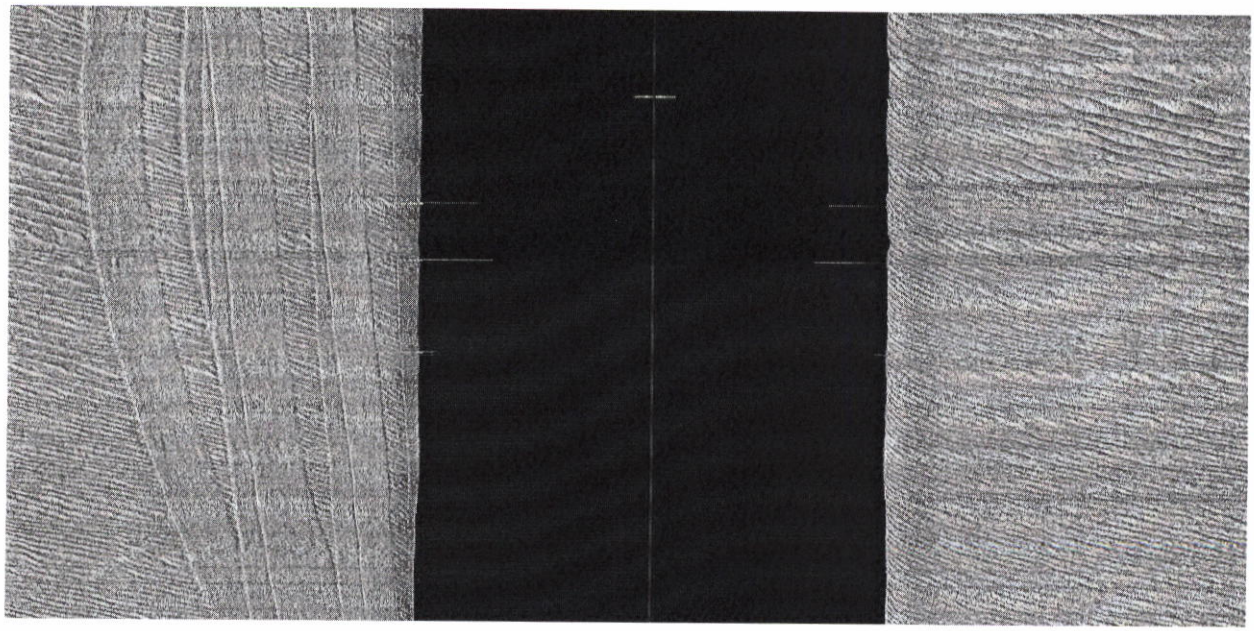

Figure 1. Apr. 2004 experimental transect, post-dredging left side, not dredged right side

The first experiment was completed on 2-3 August after 118 days of benign summer conditions. Figure 2, shows the changes that occurred to the seabed, i.e. the return of naturally occurring sand waves and the dissolution of the dredge tracks. Thus, the sediments had returned to natural background conditions by at least 118 days after dredging.

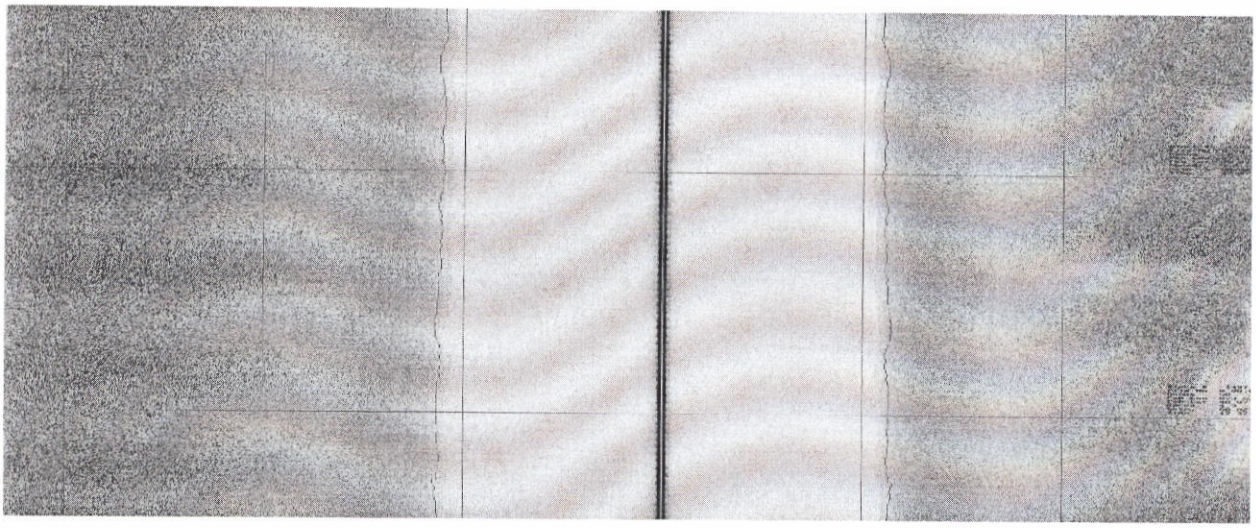

Fig. 2. Aug. 2004 experimental transect side scan sonar record

The second experiment took place between 4-5 November 2004 and 21-22 December 2004, a period of 47 days. Like April, November can be considered a transitional month for the area in which the experiment was conducted. However unlike April, November is when meteorological and oceanographic conditions transition from low energy in the summer to high energy in the winter. Due to the high-energy environment the dredge tracks created and observed in November were barely discernable in December, only 47 days later. Figure 3 shows typical bottom for November with no evidence of fishing.

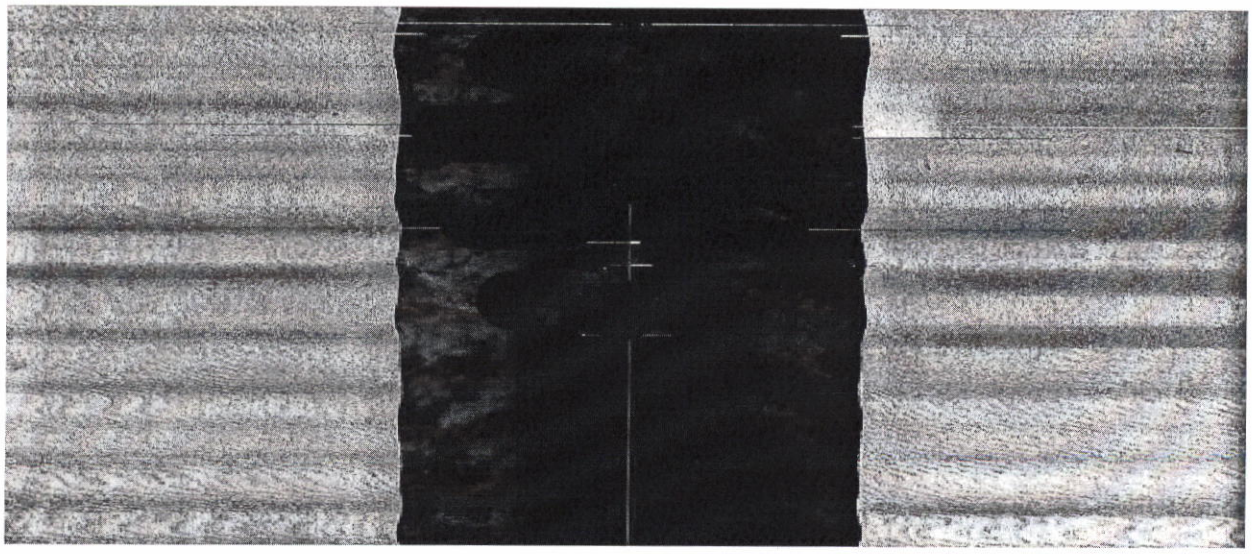

Fig. 3. Nov. 2004 control transect side scan sonar record

Immediately after dredging in November the side scan images clearly show drag marks along the bottom of the experimental transect (Fig. 4).

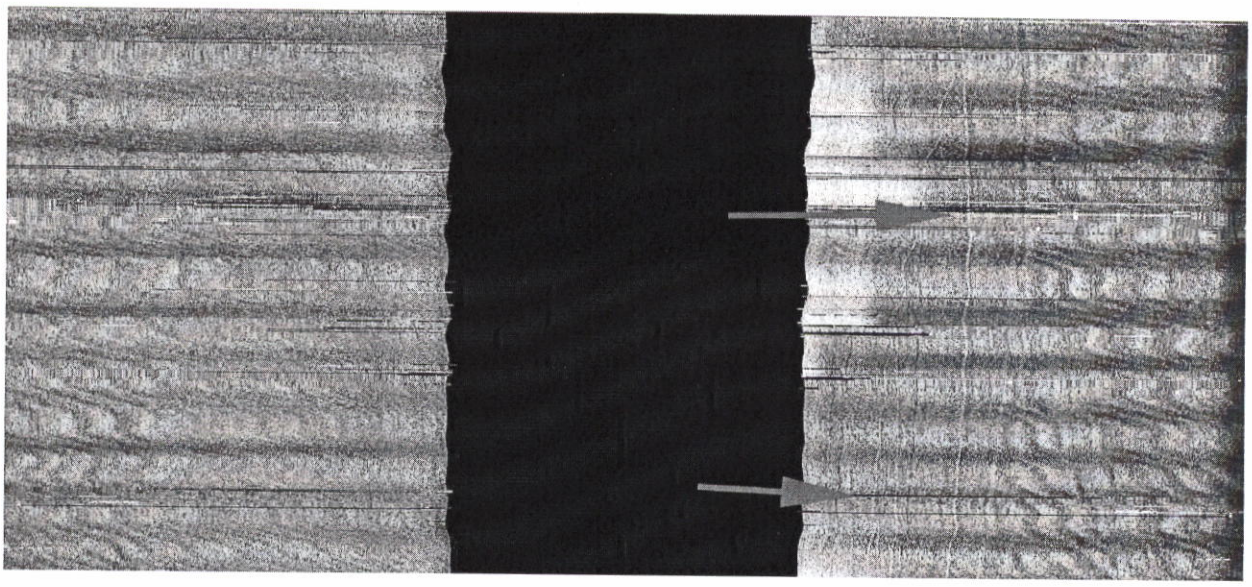

Fig. 4. Nov. 2004 post-dredging side scan sonar record with arrows indicating dredge marks

The December survey of the control transect demonstrated evidence of natural changes in the substrate by the disappearance of small sand waves but retention of larger sand ridges. The sonar survey of the experimental transect in December indicated isolated remnants of the November dredging but basically the experimental transect had returned to pre-dredge conditions by 47 days after dredging (Fig. 5).

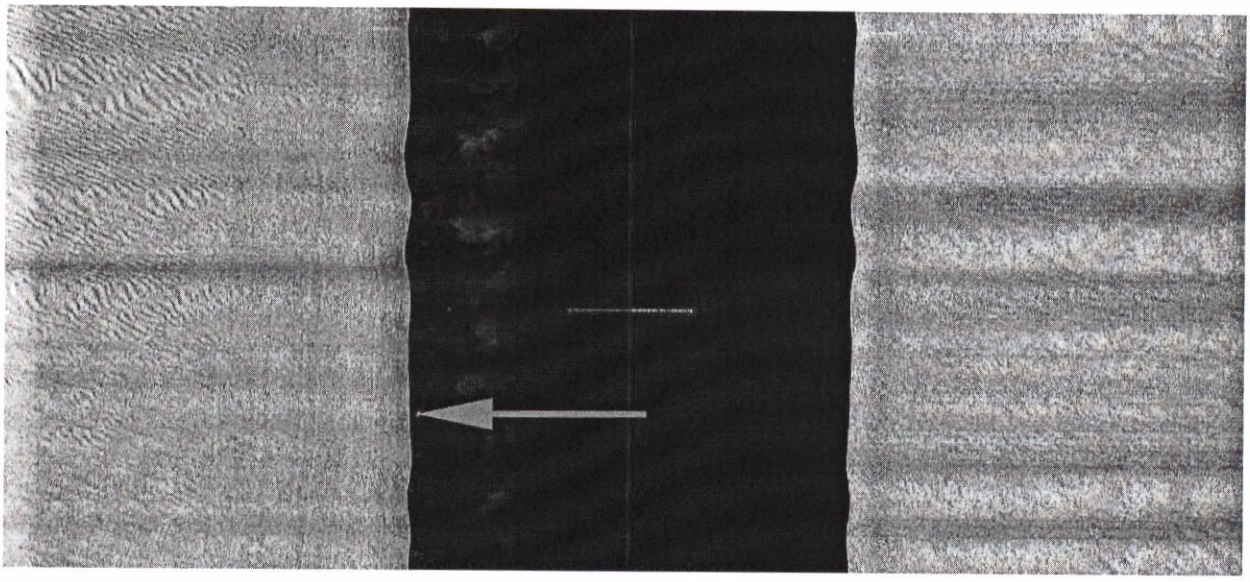

Fig. 5. Dec. 2004 post-dredging side scan sonar record with arrows indicating dredge marks

The drop video camera images of the control transect and pre-dredged experimental transect showed a natural bottom with sand waves. Figure 6 is representative of the experimental transect sediments after the effects of a winter season and before it was dredged. In Fig. 6, pebbles on the crest of a small sand wave with finer material in the sand wave troughs on each side are evident. The most abundant benthic fauna consisted of sand dollars, hermit crabs, burrowing sea anemones, and snails. The most abundant non-living material was stones, pebbles, sand, and shell hash. The drop video camera also showed differences in the control and post-dredged experimental transect. Approximately three hours of videotape were obtained and subsequently copied and reviewed.

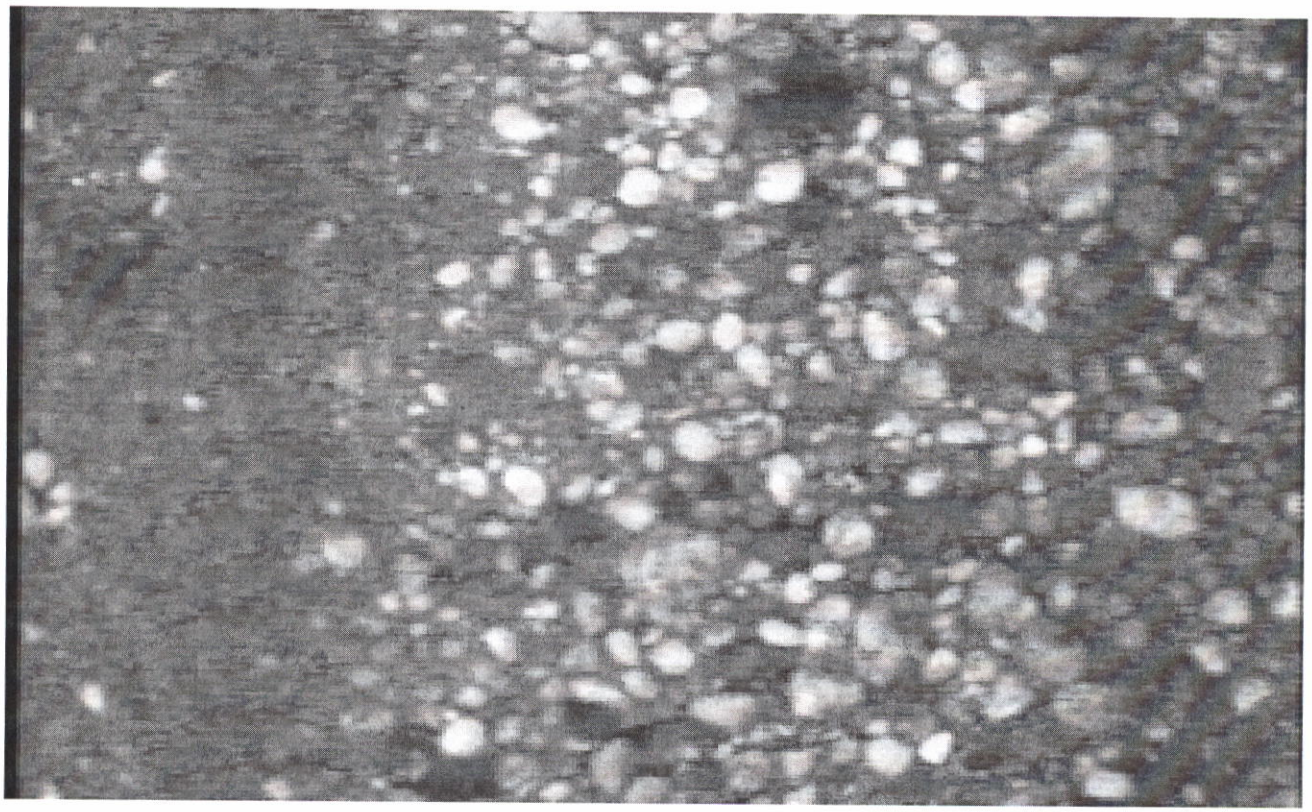

Fig. 6. Drop video camera photograph of the experimental transect bottom before dredging

Dredging by the two 15 foot (4.6m) wide scallop dredges resulted in the flattening of the sand waves, partial burial of the pebbles and shells that had been on the sediment surface, creating a finer surficial sediment and the sorted material, e. g. stones, pebbles, and broken shell, which had been in the troughs was now more evenly distributed (Fig. 7). Some of this material had been pushed into the finer sediments, probably by the dredge's cutting bar. The sediments after dredging were obviously more homogenous than before dredging was completed. Interestingly, the burrowing sea anemones (probably *Ceriantheopsis americanus*) appeared unaffected by the dredging. During the summer of 2004 there were no major storms in the experimental area so the oceanographic and meteorological conditions were representative of a normal summer season.

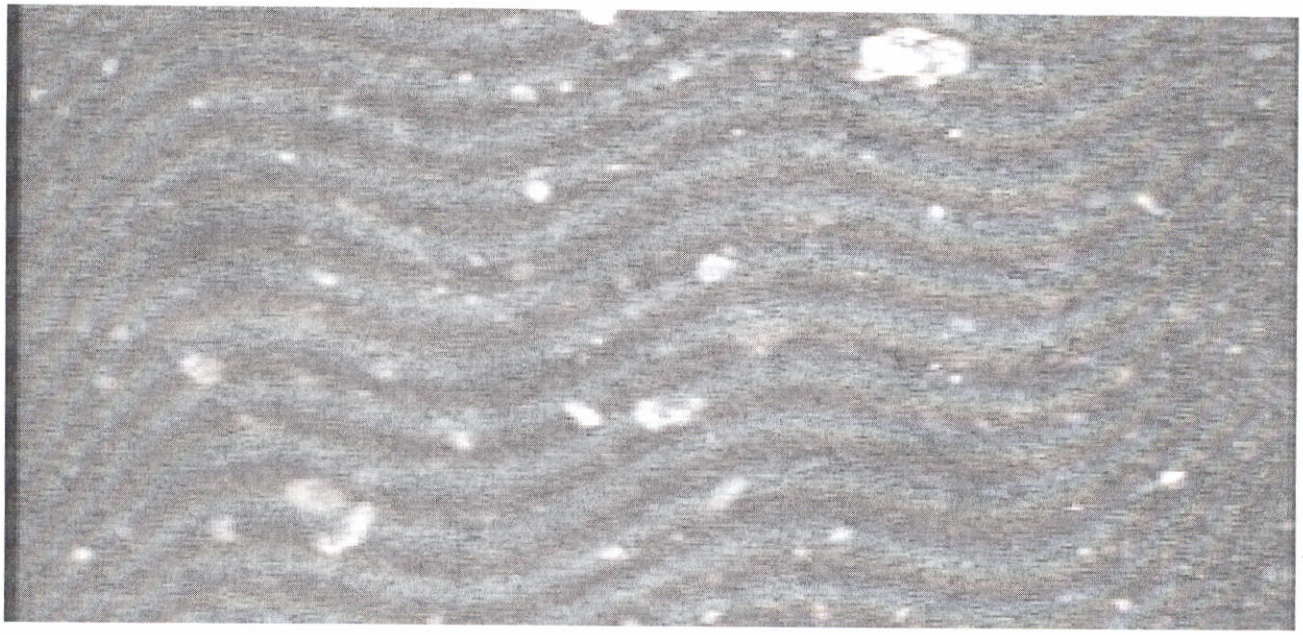

Fig. 7. Drop video camera photograph of the experimental transect bottom after dredging

It is evident from Fig. 8 that routine summer conditions returned the dredged sediments to pre-dredge conditions. The sand waves have been restored, albeit on a smaller scale than before dredging, and the benthic fauna have re-established themselves (note the burrowing sea anemone in the center right of the figure). The drop camera videotapes taken in November and December 2004 indicated a similar return to pre-dredge conditions.

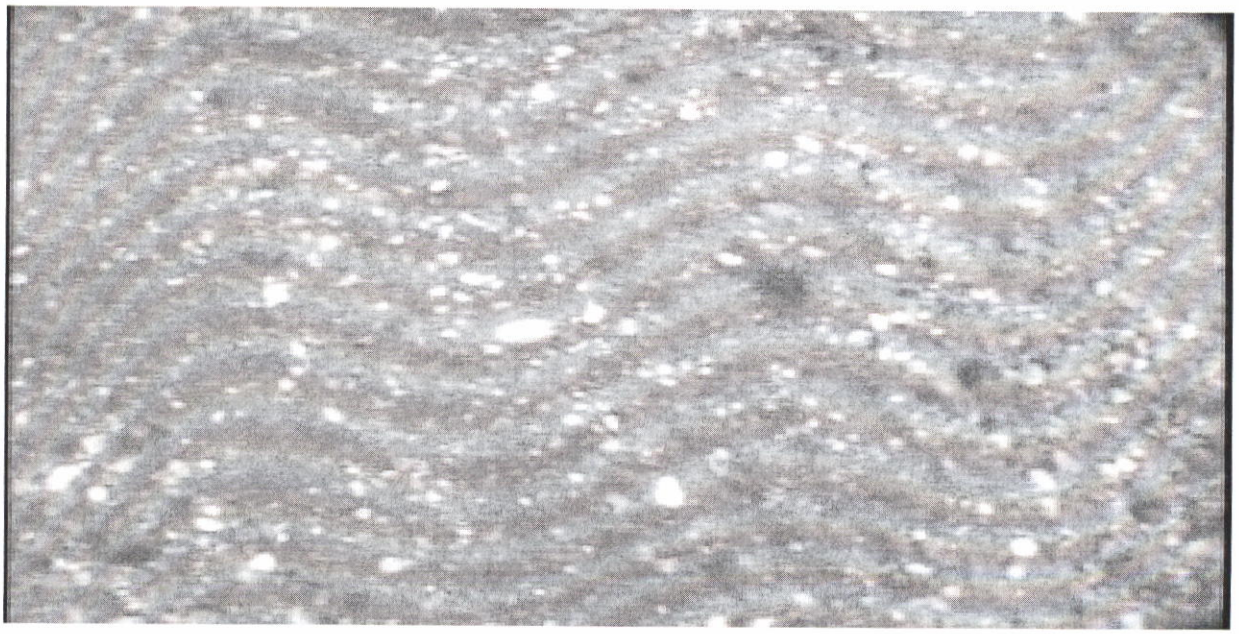

Fig. 8. Drop video camera photograph of the experimental transect 118 days after dredging

Biological samples were obtained by dredging on cruises 1, 3, and 4. Biological sampling was accomplished on each dredge on each tow. The data were recorded on log sheets and then placed into an Excel spreadsheet. Standard biomass (kg) was compared between each cruise and the biological data were analyzed for species diversity and dominant species using the Shannon-Weaver Index (H'). All fish species were enumerated, weighed, and measured. Little skate, winter flounder, and windowpane flounder were the major fish species. The invertebrates were also weighed and enumerated. Standard biomass (kg) without transformation was compared between each cruise. Given the large amount of sand dollars (*Echinarachnius parma)* that was obtained from cruise one and cruise four the cruises were compared with and without the sand dollars so as to view the data with out any outliers that would cause the data to be skewed. The catch of sand dollars varied extremely upon the direction in which the dredge was towed. The drop video camera showed a heavy concentration of sand dollars on the western end of the experimental transect. When the dredge was towed east to west the catch of sand dollars was great (340-455 kg/tow) but when the tow was west to east the catch was only1-4 kg/tow. Obviously when the tow was west to east the sand dollars had a nautical mile in which they could escape from the dredge through the twine top or chain links. Conversely, if the tow was from east to west, immediately after the dredge caught the sand dollars it was retrieved and there was no time for the sand dollars to escape. Because the catch of sand dollars was dictated by the direction of the tow we considered the total biomass with and without the sand dollars. By far the dominant invertebrate, by weight and numbers, was the sand dollar ((*Echinarachnius parma*) on cruise 1 and to a much lesser extent on cruise 4 (Fig. 9). Cruise three had no dominant species. When the biomass of the sand dollars was removed from the total biomass of each cruise there was no significant differences between the cruises quantitatively, indicating that in both experiments the experimental transect had recovered to its pre-dredge condition (Fig. 10).

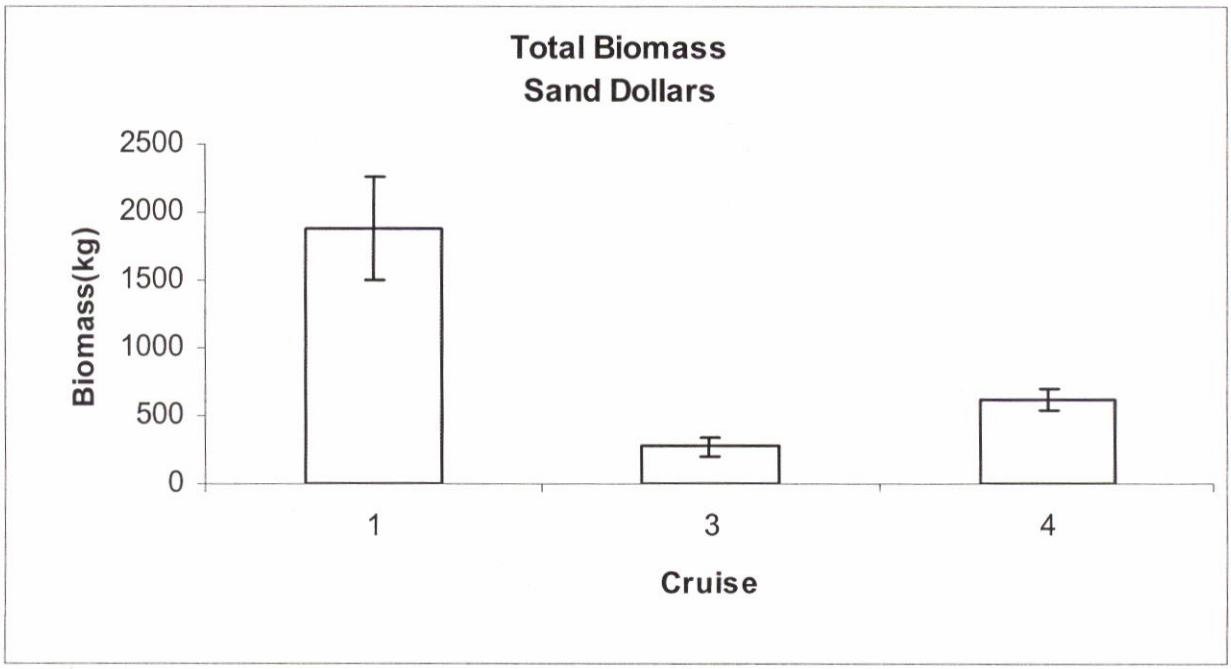

Fig. 9. Total Biomass by Cruise with Sand Dollars

The error bars in the biomass graphs were set at an error amount .05 level, 5 %, and a standard deviation of 1. The Shannon-weaver index (H') was used to assess species diversity within the experimental transects benthic community. The diversity index was calculated using natural logs to obtain a unit free entropy number.

$$H = -\sum_{i=1}^{S} p_i \ln(p_i)$$

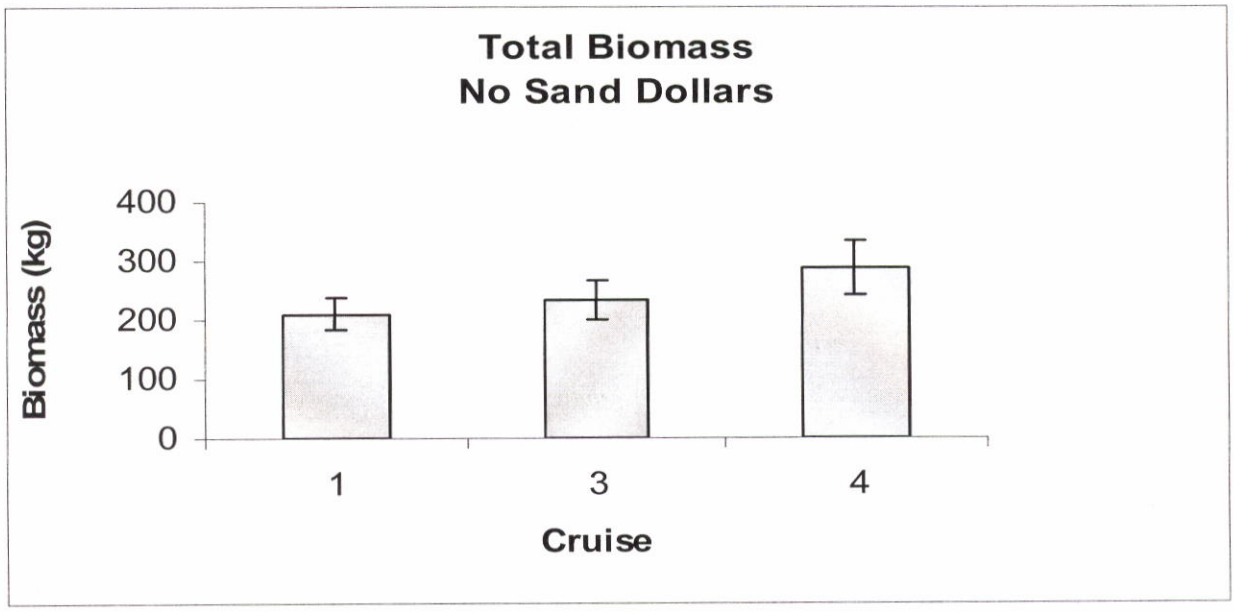

Fig. 10. Total Biomass by Cruise without Sand Dollars

The species diversity (H') for cruises one and four indicate that one species, sand dollars dominated over the benthic community. Data from cruise three indicated that there was no single species that dominated over the community. When species diversity was calculated without the sand dollars diversity could not be accredited due to the H' numerical value. Therefore when the sand dollars are not included the index values could not determine a single dominant species.

Shannon-Weaver Index (H')		
Cruise	**Sand Dollars**	**No Sand Dollars**
1	1.100036455	2.284768654
3	2.498912845	2.381813705
4	1.406111296	1.759672551

Table 1. Shannon-Weaver diversity index (H') for cruises 1, 3, and 4

The total biomass data clearly indicate that dredging did not have any lasting effects upon the abundance of benthos over time. The Shannon-Weaver diversity index showed sand dollars

to be the dominant species on cruises 1 and 4 there was no indication that such numerical and biomass dominance was influenced by dredging. Cruise 1 H' value was significantly different from the H' value of cruise 3 when both cruises were pre-dredge values. Cruise 1 H' value was closer to the cruise 4 H' value although cruise 4 was a post dredge cruise. When sand dollars were excluded from the Shannon-Weaver analyses the H' of all three cruises were very close albeit cruise 4, the post dredge cruise had a slightly lower H'. The Shannon-Weaver diversity index also did not indicate any trend due to dredging.

2. No significant problems were encountered which resulted in less than satisfactory or negative results.

3. The results of this project are applicable only to like environments, e.g. depth, sediment type, latitude, and may not be able to be extrapolated to other environments. Projects using similar instrumentation and methodology should be conducted in other environments that support scallops and the scallop fishery to determine the effects and recovery times of dredging in those areas.

G. Evaluation

The project's goals and objectives were met 100%. Although our original plan was to follow the dredged transect through one year of recovery the unexpected rapid recovery during the first months of the project allowed us to conduct a duplicate experiment within the same year's with no additional cost. The second experiment collaborated the data from the first experiment and also allowed us to determine the recovery rate of the area at a different time of the year. Although not a part of the original proposal we initiated grab sampling at the drop video camera stations to retrieve sediment samples for grain size analyses. The reason was to have another indication of the effects and recovery rate of the dredging by determining if the grain size variables changed after dredging and if so did they return to pre-dredge values over time. Some of the samples have been analyzed but there are still many samples left. The slowness is basically due to the fact that there is no funding in the projects budget explicitly set aside for grain size analysis. It is hoped that we will be able to transfer unused funds in the side scan sonar budget to support the completion of the grain size analyses.