Recolonization of the Mill-Quinnipiac River
Disposal Mound (MQR)
Results of a REMOTS Survey, August 1992

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13. ABSTRACT

A field survey at the Mill-Quinnipiac River Disposal Mound (MQR) was conducted to assess the recolonization status one year after a reconnaissance survey indicated an abrupt decline of benthic habitat. MQR, located in the Central Long Island Sound Disposal Site (CLIS), is a capped dredged disposal mound formed during the 1982-1983 disposal season. This report presents results from the August 1992 MQR REMOTS survey.

Twenty-one stations at MQR were occupied, and triplicate REMOTS photographs were taken at each station. Results of the 1992 REMOTS survey were assessed relative to a similar survey from 1991. All of the REMOTS parameters indicated that benthic conditions had improved at MQR over the year interval between the two surveys.

Historical REMOTS data from several CLIS capped mounds and the CLIS reference area were compared with the MQR results. Cycles of stress and recovery were present at all stations surveyed. However, the regressive decline in benthic habitat between 1987 and 1991 at MQR suggested an episode of bottom disturbance at that mound sometime before the 1991 survey. The 1992 data indicated that MQR is currently in a recovery phase. Determining the cause of the substantial decrease of habitat quality and subsequent slow recolonization at MQR is important in developing long-term management options for this mound.

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EXECUTIVE SUMMARY

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1.0 INTRODUCTION

1.1 Disposal and Biological Monitoring History at MQR

The Mill-Quinnipiac River Disposal Mound (MQR) is located in the southwest quadrant of the Central Long Island Sound Disposal Site (CLIS), approximately 6 nautical miles south of New Haven Harbor, CT (Figure 1-1). MQR is a capped mound formed by the deposition of dredged material during the 1982-1983 disposal seasons. The mound has been periodically monitored by the New England Division of the US Army Corps of Engineers (NED) as part of the Disposal Area Monitoring System (DAMOS) Program since the formation of the mound.

The capped mound is actually a complex interlayered mound consisting of material from the Mill River, the Quinnipiac River, Black Rock Harbor, and New Haven Harbor. The disposal history of the MQR mound was compiled in recent DAMOS reports (SAIC 1994, Murray 1992). Although the mound has not received dredged material since 1983, recent attention has been focused on MQR since routine monitoring data have indicated anomalous recolonization relative to other CLIS disposal mounds formed at the same time.

A history of habitat quality at several CLIS sites as documented by Remote Ecological Monitoring of the Seafloor (REMOTS®) technology was compiled to chart the relative progress of MQR. Three years after disposal, it was noted during the monitoring survey of 1986 that "MQR continues to have the slowest rate of benthic ecosystem recovery . . ." (SAIC 1990a). The following year, REMOTS® data indicated improving conditions, although still below CLIS reference levels (SAIC 1990b).

Monitoring activity has increased since June 1991 (Table 1-1) when the results of a REMOTS® survey indicated an abrupt decline of habitat indicators (Wiley and Charles 1994). One gallon of surface sediment also was collected from near the center of the MQR mound for a 10-day amphipod bioassay in August 1991; percent survival rates for amphipods exposed to MQR sediments ranged from 10 to 45%, as compared with control station survival rates which ranged from 75 to 100%. Because of these results, a series of investigations was initiated following the tiered monitoring protocols designed for the DAMOS Program (Germano et al. 1994). The most recent REMOTS® survey was conducted in August 1992 to assess the recolonization status one year after the June 1991 survey which triggered the investigations.

1.2 REMOTS® Survey, Summer 1992

Twenty-one stations were occupied during the 1992 survey at MQR. Triplicate REMOTS® photographs were taken at each station. In addition to the REMOTS® survey, sediment was collected for potential use in an amphipod bioassay. The sediment was

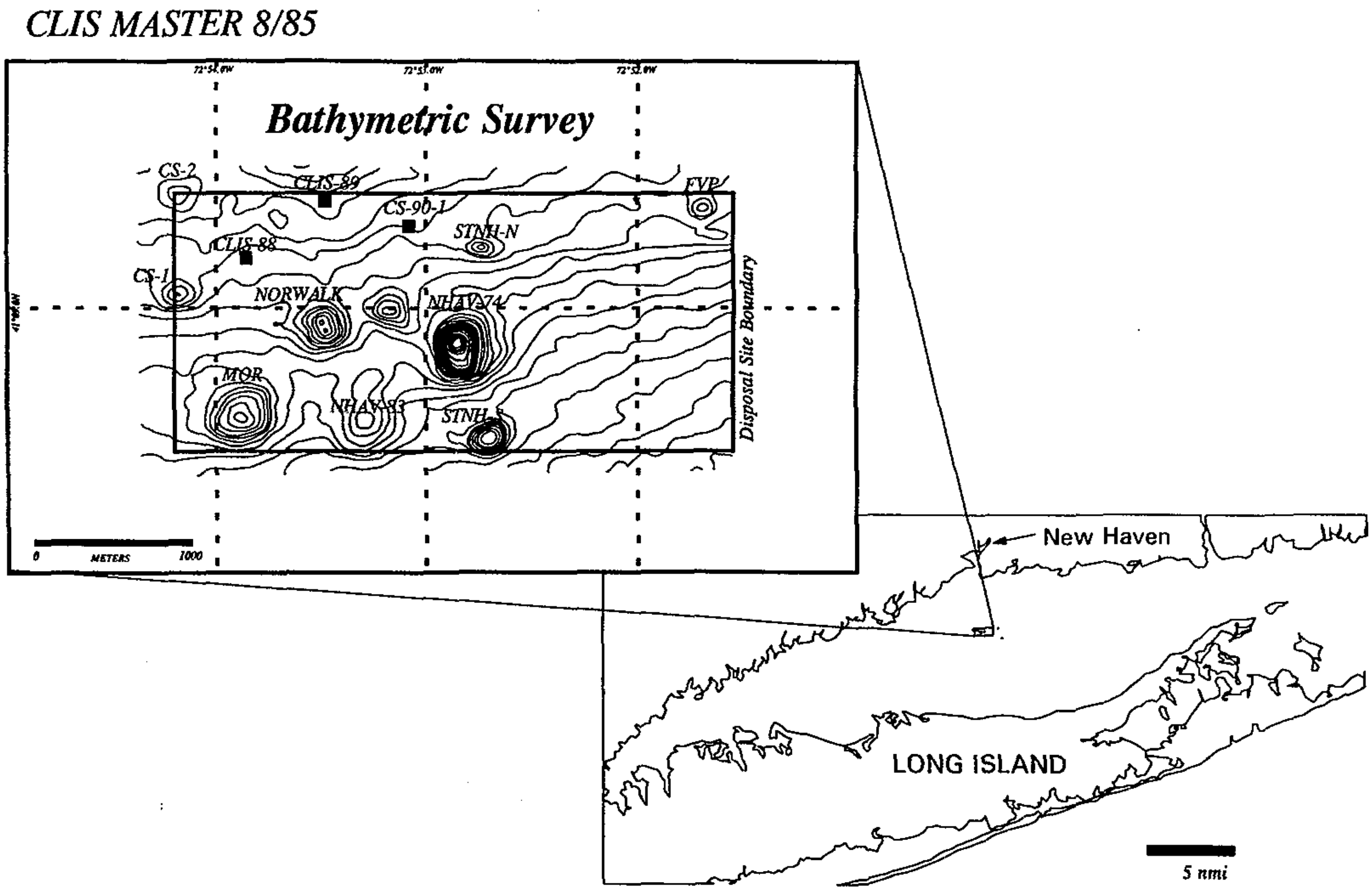

Figure 1-1. Long Island Sound and the Central Long Island Sound Disposal Site

Table 1-1

Summary of DAMOS Activity at MQR

TIME	DREDGING OPERATIONS	SURVEYS
March-June 1982	Mill/Quinnipiac Rivers	Predisposal, Postdisposal
January 1983		Interim Disposal
March-May 1983	Black Rock/New Haven Harbors	Predisposal, Postdisposal
August 1983		Postdisposal
September 1984		Monitoring
August 1985		Post-Hurricane Gloria
July 1986		Monitoring
August 1986		Tissue/Body Burden-Metals Analyses
August 1987		Monitoring
June 1991		REMOTS®
August 1991		Sediment Cores/Chemistry, Amphipod Bioassay
September 1991		Body Burden[1]
December 1991		Surface Sed/Chem Bathymetry
August 1992		REMOTS®, Amphipod Bioassay[2]

[1] No samples taken, worm density too low
[2] Not analyzed

archived from both MQR and the CLIS reference area in anticipation of the REMOTS® results.

Results of the 1992 REMOTS® survey were assessed relative to both the CLIS reference area results from 1991 (CLIS REF was not visited in 1992) and the 1991 MQR results. REMOTS® data indicated an improvement in benthic conditions at MQR over the year interval between the two surveys. However, the benthic habitat was still anomalous relative to the CLIS reference area.

2.0 METHODS

2.1 REMOTS® Sediment Profile Analyses

A REMOTS® survey of the MQR mound was conducted on 3 August 1992 aboard the *R/V UCONN*. A total of 21 stations were occupied in a grid radiating from the center of MQR (Figure 2-1). The station density was increased relative to previous surveys at MQR in order to assist NED managers in determining the area potentially in need of capping. Three replicate photographs were taken at each station. The bathymetric center was defined from bathymetry data collected in December 1991. Only the center station was reoccupied between the June 1991 and August 1992 REMOTS® surveys.

The REMOTS® sediment profiling camera collects cross-sectional photographs of approximately the top 20 cm of the sediment column. The photographs are digitized and analyzed for several parameters indicative of the sediment colonization status, oxidation condition, and physical condition of the sediment including the grain size distribution and surface disturbance of the top of the sediment mound. A detailed description of REMOTS® photograph acquisition, analysis, and interpretive rationale is given in DAMOS Contribution No. 60 (SAIC 1989a).

2.2 Amphipod Bioassay Sediment Collection

In addition to the REMOTS® survey, sediment was collected both at MQR and the CLIS reference area for an amphipod bioassay using a Van Veen grab sampler. One gallon of sediment was collected from MQR and the reference area. The sediment was composited from five separate grabs at MQR and three grabs at the CLIS reference area, stored refrigerated, and transported to SAIC's Narragansett Environmental Testing Center. Bioassay samples were collected for the contingency that the initial review of REMOTS® results indicated complete biological recovery of the mound. In the event that recovery had occurred, the bioassay was intended to provide further assurance that the surface sediments were not toxic, despite the REMOTS® results. Prior to this survey, the NED DAMOS Program Manager had directed that additional cap material should be placed at MQR when available. If REMOTS® results indicated anything less than complete recovery (Stage III, Organism-Sediment Indices [OSIs] greater than 6), then capping would proceed, and bioassay tests would not be required. Results of REMOTS® analyses from this survey indicated that benthic ecological factors have improved over the 14-month period since the last REMOTS® survey in June of 1991, so bioassay analyses were not conducted.

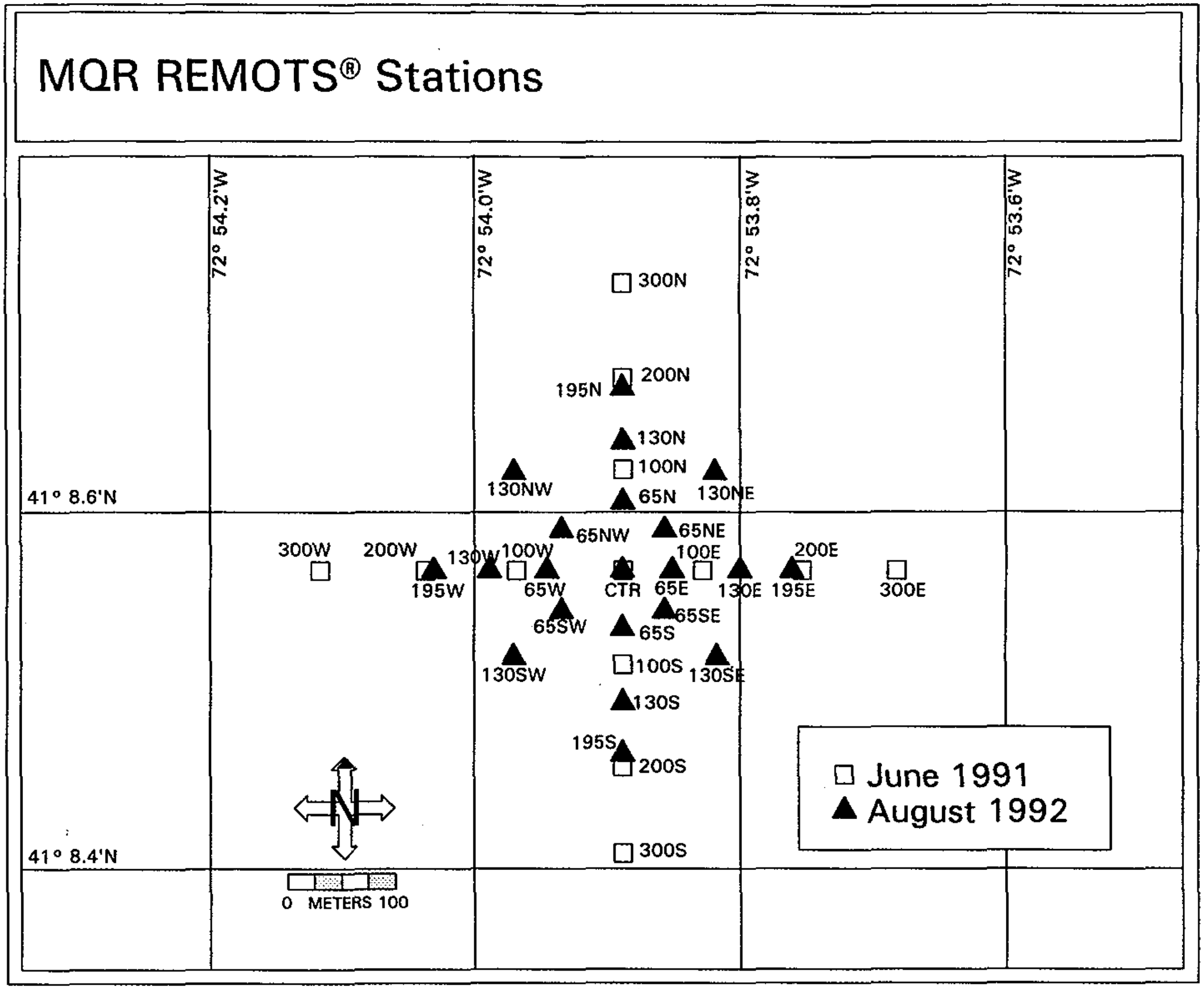

Figure 2-1. REMOTS® station locations at MQR, June 1991 and August 1992 surveys

3.0 RESULTS

Three replicate photographs were successfully taken and developed at all 21 stations (Appendix). Only one replicate photograph at 130NE was not analyzed; the obscured image was attributed to either a collapsed burrow or an artifact of the camera (pullout).

Results from this year's survey are discussed in terms of (1) the distribution of quantified REMOTS® parameters over the mound, (2) the benthic habitat, as measured by successional stages of organisms and the multiparameter Organism-Sediment Index (see below), and (3) specialized observations which are important in describing the state of MQR. Since none of the CLIS reference areas were sampled in 1992, MQR REMOTS® photographs were compared to reference data from the 1991 survey. Results from the most recent survey were also compared with results from the June 1991 survey for each category. The station locations were not identical between the two surveys due to the increased station density of the 1992 survey (Figure 2-1). Because of this discrepancy, only stations within 200 meters of the center station were used for comparison purposes.

Results of REMOTS® analyses indicated that benthic ecological factors have improved over the 14-month period since the last REMOTS® survey in June of 1991. Although benthic conditions have improved at MQR since 1991, they remain below reference levels. These indications of recovery were not considered sufficient to alter plans of capping. For this reason bioassay analyses were not conducted.

3.1 Distribution and Ranges of REMOTS® Parameters

3.1.1 Sediment Parameters

Sediment parameters which are documented during REMOTS® analyses include grain size modes and the presence of sedimentary features like mudclasts, shell layers, and surface sediment bedforms. Finally, the presence and depth of sediment which appears to be dredged material (rather than background sediment) is documented.

Grain size ranges are estimated visually by overlaying a grain size scale on the image. The grain size scale was prepared by photographing a series of Udden-Wentworth size classes through the REMOTS® camera (SAIC 1985). A "major mode" (the most common grain size) and the range of grain sizes present are identified.

Ambient central Long Island Sound sediment consists generally of silt and clay (>4 phi). The 1992 MQR survey indicated a similar distribution of grain sizes but included a small fraction of coarser grained material (major mode 3-4 phi; Appendix). Overall, the grain sizes reported for the 1992 survey were slightly coarser than both the CLIS reference area and MQR results from the June 1991 survey. All but one MQR station in the 1991 survey consisted of a >4 phi grain size major mode.

In addition to the 1991 MQR stations consisting of overall finer grain sizes, a higher percentage of the 1991 stations contained numerous mudclasts. The presence of mudclasts is indicative of surface sediment disturbance (presumably by physical bottom scour or faunal activity). Other evidence of surface disturbance included erosional features such as scours and rip-ups (Appendix). Mud clasts documented at stations both in 1991 and 1992 were primarily oxidized, but some reduced mudclasts were present during both surveys (Appendix; Wiley and Charles 1994).

All of the REMOTS® replicates penetrated relic dredged material; only two replicates at 195W and one replicate at 195N penetrated below the dredged material layer. Average thicknesses of relic dredged material were no different between the 1991 and 1992 surveys. No material was described as "fresh" dredged material in the 1992 photographs. In contrast, more than half (18 out of 37) of the 1991 replicate photographs were described as containing "fresh" dredged material, although no fresh dredged material has been disposed at MQR since 1983. The presence of material which appears fresh is strongly indicative of recent disturbance.

3.1.2 Boundary Roughness

Boundary roughness is the vertical distance (parallel to the film border) between the highest and lowest points of the sediment-water interface. The presumed origin of this small-scale topographical feature is recorded so that inferences can be made as to surface character. Two types of boundary roughness are usually present: biological and physical. Biological disturbance causes boundary roughness primarily through macrofaunal activity. Physical disturbance can be caused by anything from waves or currents to anthropogenic effects like bottom trawls.

Replicate-averaged boundary roughness values from the 1992 survey ranged from 0.34 to 0.96 cm. Boundary roughness values were within those measured at the CLIS reference replicate stations in 1991 (0.21 to 1.9). Averaged values measured at MQR in June 1991 were considerably larger and ranged from 0.35 to 2.43 cm. Individual replicates in 1991 reached a maximum boundary roughness of 4.81 cm (Figure 3-1).

The presumed cause of boundary roughness is documented during analysis of REMOTS® photographs. The three categories described during REMOTS® analysis are biological, physical, and indeterminate. A mature and undisturbed benthic environment will be dominated by biological disturbance, as evidenced by the majority of stations (86%) at the CLIS reference area classified as biological roughness type. In the 1992 MQR survey, approximately half of the replicates were classified as biological and half as physical, in

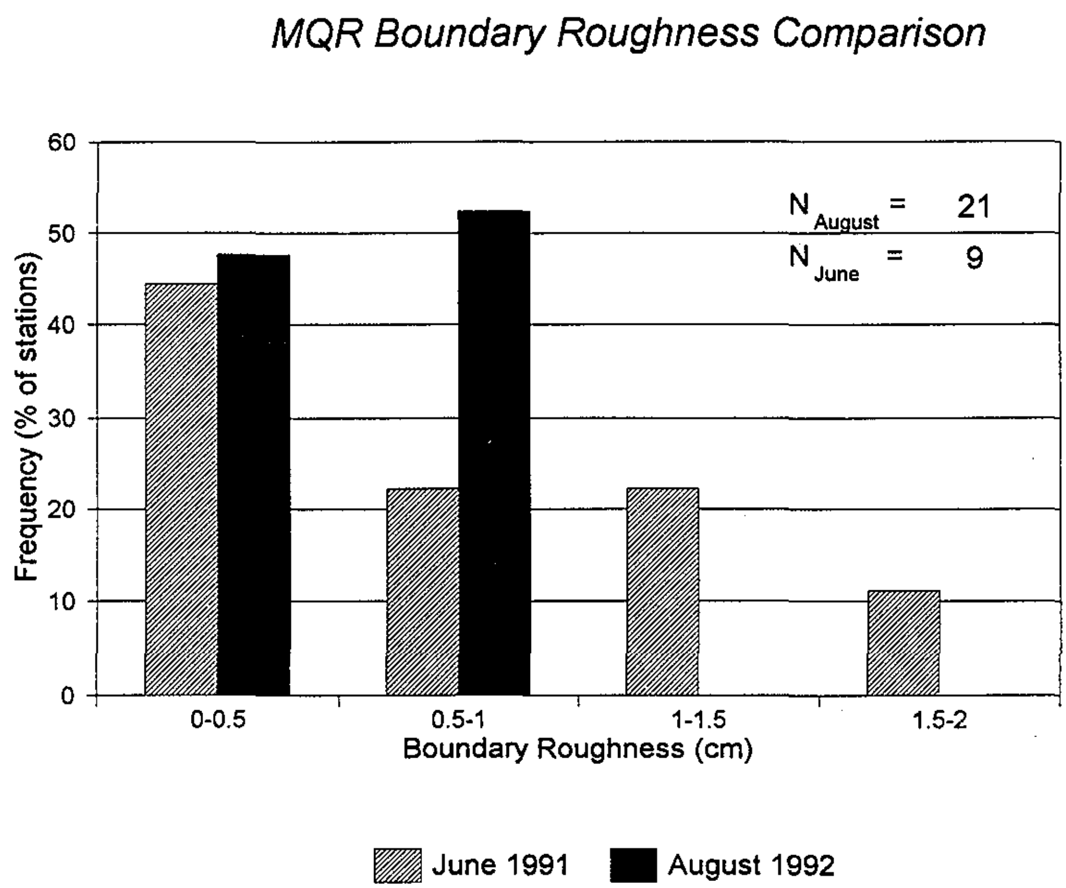

Figure 3-1. Frequency distribution of boundary roughness values from the 1991 and 1992 REMOTS® surveys at MQR

comparison with the June 1991 survey at MQR, where replicates were dominated by indeterminate causes of boundary roughness.

3.1.3 Apparent Redox Potential Discontinuity

The Apparent Redox Potential Discontinuity (RPD) depth is the depth of the upper oxygenated sediment layer. This value is an important indication of dissolved oxygen conditions within sediment pore waters and is a function of the supply of molecular oxygen from the overlying sea water, and the consumption of oxygen in the sediment. Since the actual oxygen status in the sediment is not measured, the apparent RPD is estimated by measuring the thickness of the layer of high reflectance; reduced sediments are usually grey to black and contrast with the lighter oxygenated sediments.

Replicate-averaged RPD values ranged from 0.54 to 2.00 during the 1992 survey compared to the CLIS reference area in June 1991 (1.49 to 2.71). The range of RPDs in the replicates has increased since the June 1991 sampling (Figure 3-2). The range of replicate-averaged apparent RPD values in June 1991 was 0.21 to 1.96.

3.2 Habitat Quality at MQR

3.2.1 Infaunal Successional Stages

The mapping of successional stages is based on the theory that organism-sediment interactions follow a predictable sequence after a major seafloor perturbation (e.g., passage of a storm, dredged material deposition; Rhoads and Germano 1982). This sequence is defined by end-member assemblages of benthic organisms. Pioneering assemblages (Stage I) usually consist of dense aggregations of near-surface, tube-dwelling polychaetes. Early Stage I assemblages are then replaced (barring any disturbance) by infaunal deposit feeders (Stage II) like shallow dwelling bivalves or, as is common in New England waters, tubicolous amphipods. Stage III taxa are associated with relatively low-disturbance regimes. These infaunal invertebrates generally are head-down deposit feeders whose presence results in distinctive subsurface feeding void features. There are several divisions among these end-member groups (Figure 3-3).

Most of the replicate photographs from the August 1992 MQR survey contained either only Stage I taxa (60%) or Stage I taxa overlying Stage III (35%; Figure 3-3). No stations were classified as azoic. Successional stage results from the CLIS reference area (1991) indicated an inverse relationship, with 68% of the replicate stations displaying Stage I taxa overlying Stage III, 16% of the stations displaying only Stage I, and 16% displaying only Stage III. However, the habitat succession has progressed since the 1991 survey, when 16% of the stations were azoic, and less than 10% of the stations were classified as Stage III or Stage I overlying Stage III (Figure 3-3).

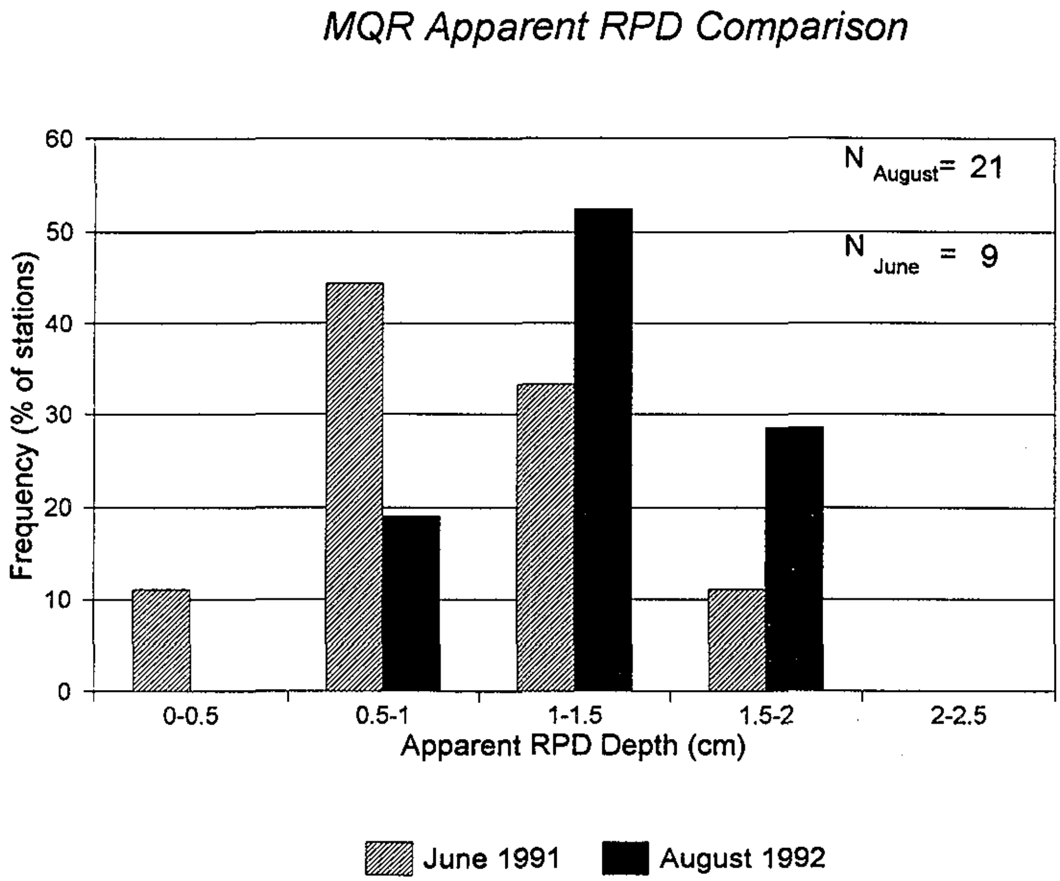

Figure 3-2. Frequency distribution of apparent RPD depths from the 1991 and 1992 REMOTS® surveys at MQR

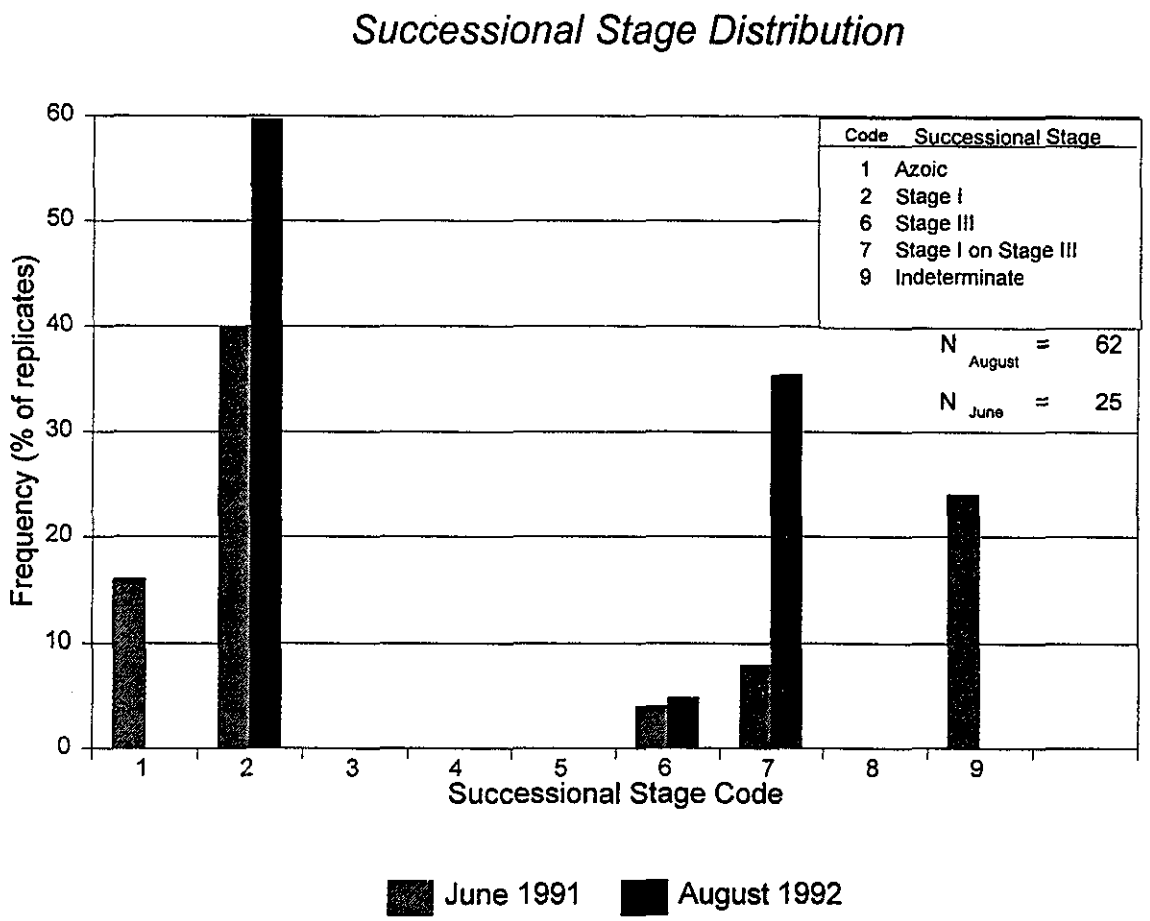

Figure 3-3. Frequency distribution of successional stages from the 1991 and 1992 REMOTS® surveys at MQR

The presence of Stage III organisms is a rough indicator of the species progression of that area. Only 20% of the replicates in the June 1991 survey at MQR contained signs of Stage III organisms. This number doubled in the August 1992 MQR survey (39%). Again, reference values were considerably higher; in the 1991 CLIS survey, 84% of the reference area replicates contained Stage III organisms.

3.2.2 Organism-Sediment Index

The apparent RPD, the successional status, and indicators of methane or low oxygen (Section 3.3) are summarized in a value called the Organism-Sediment Index (OSI). OSIs can range from -10 (no apparent macrofaunal life and methane gas present in the sediment) to 11 (aerobic bottom with a deep apparent RPD, evidence of a mature macrofaunal assemblage, and no apparent methane). The index is useful in mapping disturbance and ecosystem recovery.

OSI values can vary widely even among three replicates at the same station. The median OSI from three replicates is reported, therefore, to best represent the overall conditions at that site. Since the index is a number, it also can be useful to track historical changes at any site, if these numbers are compared with reference values.

Median OSI values from all stations of the 1992 MQR survey ranged from 3 to 7. This range is lower than the range measured at the CLIS reference area in June, 1991 (5-9). Again, the value of this indicator has improved since the 1991 survey, when the OSIs ranged from -8 to 3 within 200 meters of the center of the MQR mound (Figure 3-4).

The distribution of OSIs displays no particular spatial pattern in either 1991 or 1992 (Figure 3-5). The southern part of the mound has higher OSI values, probably due to this area being farthest from the MQR mound boundary. Since active disposal is no longer taking place, a "footprint" of activity is no longer apparent.

3.3 General Observations

3.3.1 Methane

Methane was present in both the REMOTS® surveys of 1991 and 1992. Approximately 10% of the stations from the 1992 survey contained evidence of methane, while double the number of stations (approximately 20%) within 200 meters of the center of the 1991 survey contained methane.

This persistence of methane, documented in several prior DAMOS reports (e.g., SAIC 1990a, 1990b), is the most conclusive piece of evidence presented by REMOTS® data that the capping material at MQR is conducive to the formation of methane. The presence of

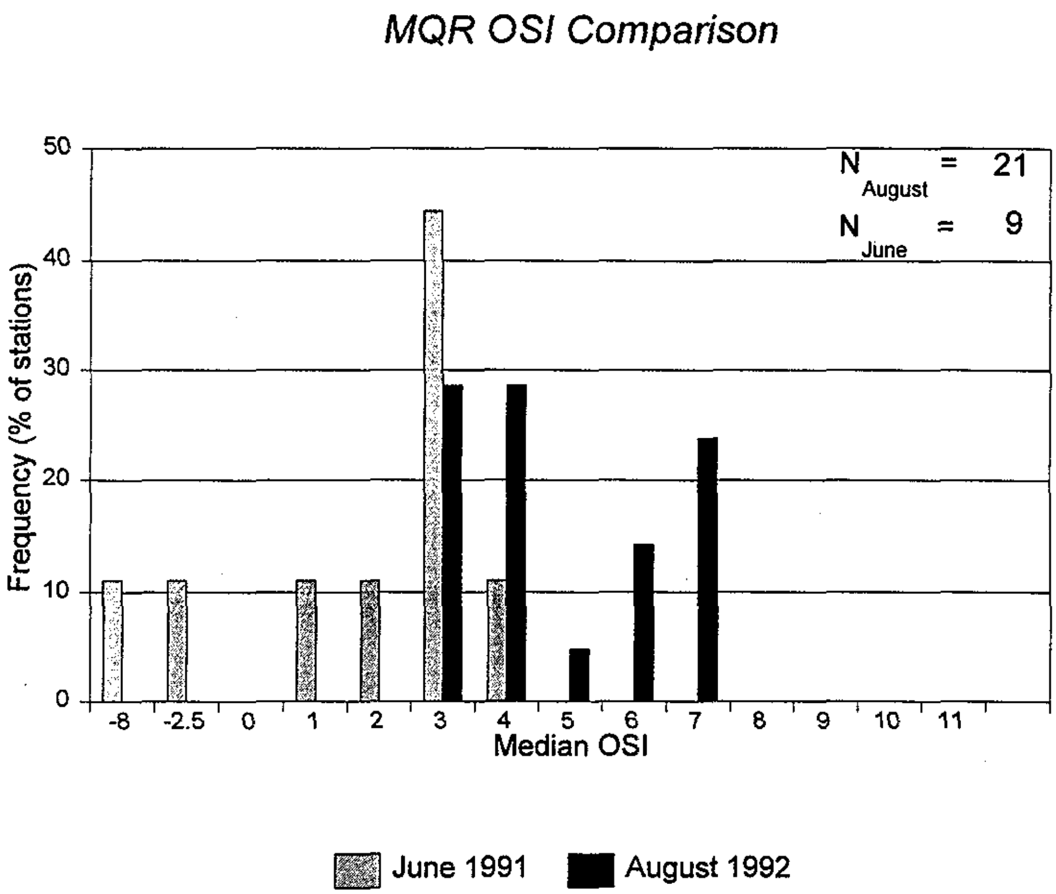

Figure 3-4. Frequency distribution of OSI values from the 1991 and 1992 REMOTS® surveys at MQR

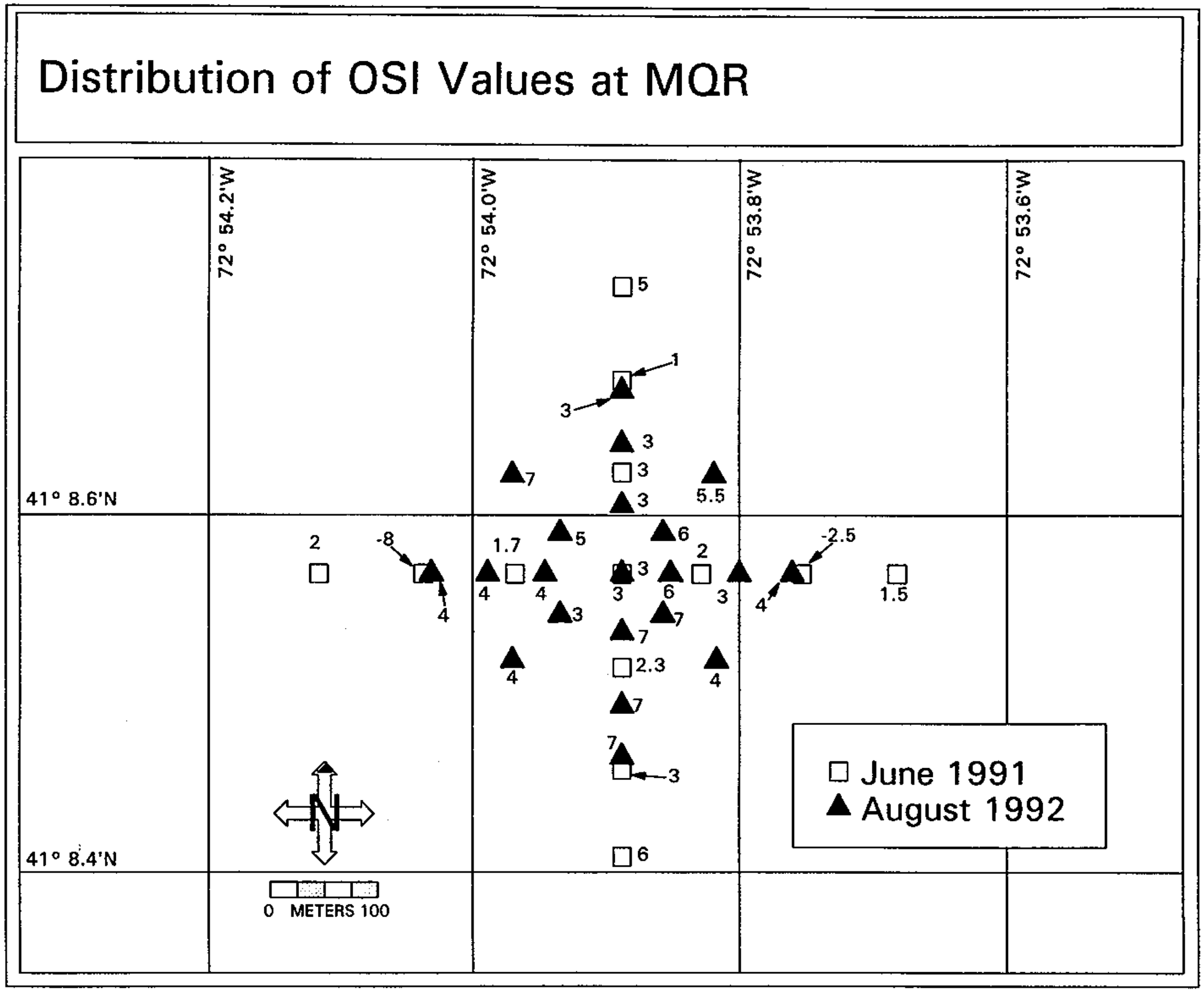

Figure 3-5. Spatial distribution of OSI values from the 1991 and 1992 REMOTS® surveys at MQR

methane is indicative of organic loading of the sediments and is easily discernable in REMOTS® photographs because of an irregular, generally circular shape and glassy texture. If methane is detected, the OSI calculation is decreased by 2. Thus, OSI values for MQR took into account this factor.

3.3.2 Low Dissolved Oxygen

REMOTS® photographs are flagged when a condition of apparent low or nonexistent dissolved oxygen (DO) exists at the sediment surface. This classification is based on the presence of reduced, low reflectance sediment at the sediment-water interface. If a sample is flagged due to low DO, the OSI calculation is decreased by 4; obviously this classification can greatly affect the final calculation of OSI.

None of the 1992 MQR stations were flagged as having low DO. Of the stations within 200 meters of the June 1991 center station at MQR, 16% were flagged as having low DO, while 2 replicates outside of this boundary (300E and 300W) also were flagged. All of the flagged samples were associated with azoic conditions.

4.0 DISCUSSION

4.1 Summary of Ecological Conditions at MQR, 1992

All of the REMOTS® parameters indicated that the benthic environment has improved in the year between the 1991 and 1992 surveys. No apparent "fresh" dredged material was observed in 1992. This was a significant difference from the results in 1991. The fresh dredged material appearance was a function of the low RPD (and low DO) conditions at several stations in 1991 combined with boundary roughness values which emulated the appearance of newly disposed dredged material. The combination of increased RPD, less methane, and the lack of low DO in 1992 resulted in overall higher OSIs relative to the 1991 survey.

Although the 1992 REMOTS® results indicate an improvement in benthic habitat over 1991, the fact remains that several parameters are still significantly out of the range of CLIS reference values. Comparing REMOTS® results between different years and stations is somewhat risky; however, the overall historical trend of OSIs at the CLIS reference area indicates that the average OSI of the undisturbed area hovers between 8 and 10. The persistence of slow recolonization at MQR and the continuing presence of methane almost 10 years after dredged material deposition suggest that there is still an inherent quality of MQR sediments which discourages normal benthic recolonization.

4.2 Historical Progression of the MQR Benthic Habitat

The DAMOS Program benefits from the fact that over ten years of data have been collected at MQR. MQR historically has been the slowest among the disposal mounds at CLIS to recover from stress. This characteristic has triggered more intensive monitoring in recent years (Table 1-1). Observations from REMOTS® surveys were summarized in order to approach the problem of MQR benthic habitat recovery from a historical context. In summarizing these data, OSI values from the CLIS reference areas were averaged for each time period the site was sampled. Historical OSIs from MQR and other CLIS dredged material disposal mounds were plotted relative to the CLIS reference area to map the long-term trends of habitat quality (Figure 4-1, Figure 4-2).

A concise summary of several CLIS mounds is necessary as a reference to the MQR mound. A complete history of the disposal mounds at CLIS was recently compiled (SAIC 1994). In the spring of 1983, contaminated material from Black Rock Harbor was disposed at several CLIS mounds including MQR, the Field Verification Program mound (FVP), and Cap Sites 1 and 2 (CS-1 and CS-2; Figure 1-1). Both Cap Site mounds and MQR were capped with material from New Haven Harbor, while FVP remained uncapped.

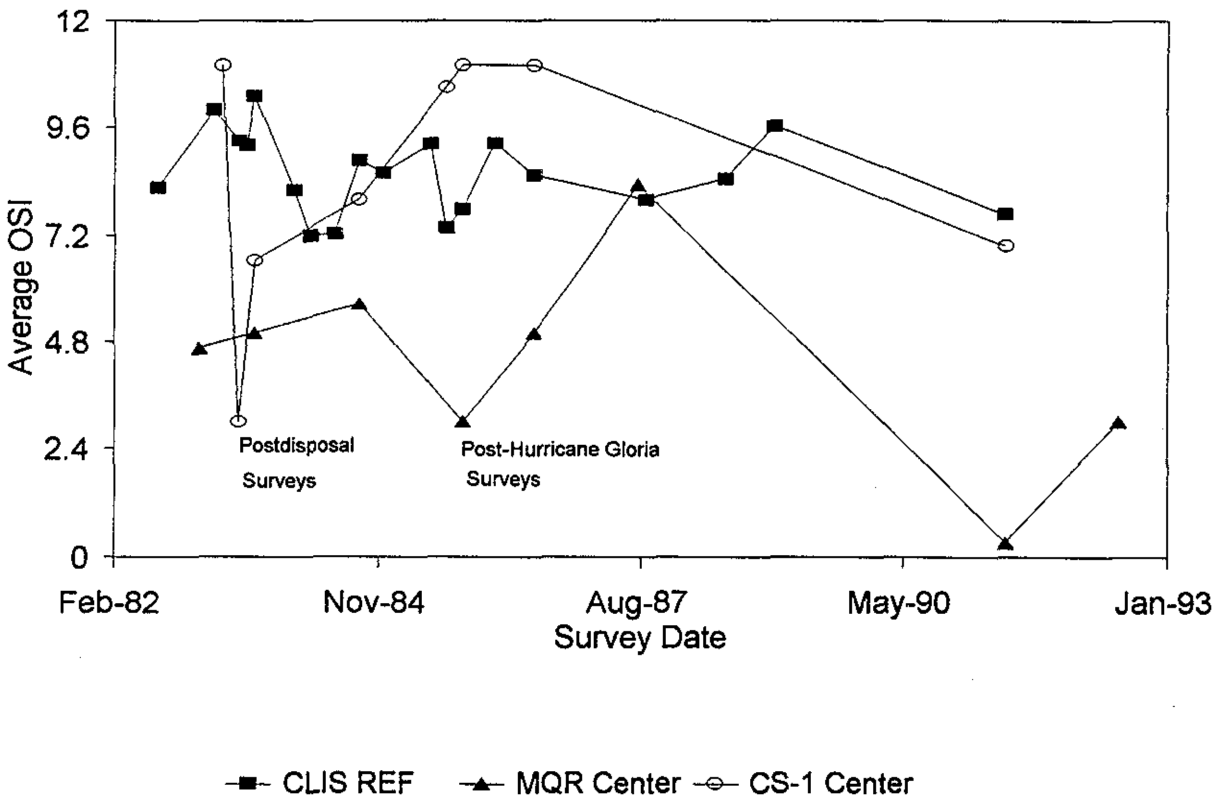

Figure 4-1. Average OSI values from the CLIS Reference Area (all stations), and data collected from the centers of MQR and CS-1

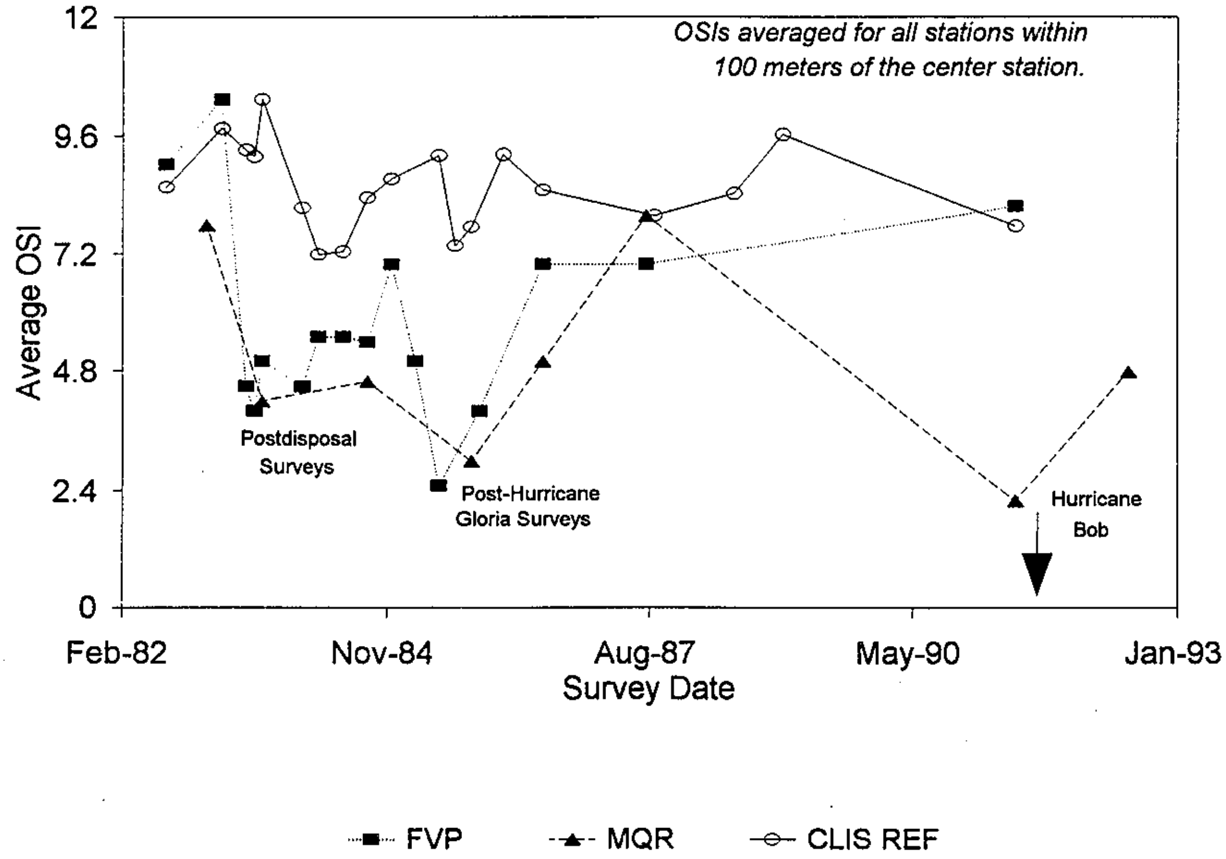

Figure 4-2. Comparison of the progression of OSI values at MQR and FVP relative to the CLIS Reference Area

REMOTS® postdisposal surveys indicated that recolonization was occurring at all of these mounds, including FVP, and that MQR was the slowest to recover. Hurricane Gloria had a substantial impact on the benthos at most of the CLIS mounds in 1985, especially the FVP mound (Figure 4-2). Following the Hurricane Gloria survey, two REMOTS® surveys in 1986 and 1987 documented the cycle of recovery following the storm and again indicated that MQR did not recover quite as quickly as the other mounds.

The 1986 survey at CLIS concluded that the lowest mean OSIs occurred at STNH-S, NH-83, and MQR, which are all located along the southern border of CLIS (Figure 1-1). One suggestion to explain this phenomenon was hypoxic bottom water conditions, concentrated at the southern rim of CLIS, which would prevent or inhibit colonization of these mounds (SAIC 1990a).

The 1986 report also noted that MQR "continues to have the slowest rate of benthic ecosystem recovery, possibly the result of chemical contamination combined with hypoxic effects." RPD values were significantly shallower than at the reference area. The low OSI values were a function of the thin RPDs, dominance of Stage I, and presence of methane. Surface sediment chemistry results from MQR indicated that the mound had statistically higher concentrations of metals and oil/grease relative to reference area values. Conversely, the FVP mound showed that trends towards shallower RPDs which had been documented in March and October of 1985 had been reversed and that the percent of stations showing Stage III had increased (SAIC 1990a).

In the following year, MQR had RPDs which were consistently deeper than the previous survey (SAIC 1990b). The presence of dredged material and pockets of methane were similar to the previous survey. Methane was noted as being unusually high and persistent in this sediment. The presence of Stage III organisms increased from 31% of replicate images in 1986 to 46% in the 1987 survey.

The OSI is sensitive to conditions which cause stress to the benthic environment. A clear example is the passage of Hurricane Gloria; surveys were conducted immediately following the storm, and the resulting change in OSIs demonstrates the substantial effects on the benthos (especially at the mound apices), most clearly displayed at the FVP mound (Figure 4-1, Figure 4-2).

Comparing MQR and FVP is appropriate since (1) they were created at the same time and (2) FVP remained uncapped and MQR capping material apparently contains some elevated levels of contaminants (Murray 1992). Figure 4-2 shows the average OSI from all stations within 100 meters of the center station for both MQR and FVP through time.

Postdisposal surveys at both MQR and FVP indicated that benthic communities of both were detrimentally affected by disposal of dredged material. Although FVP was monitored more frequently, the resultant OSIs from both mounds are not significantly different.

Hurricane Gloria affected FVP more severely than MQR; however, FVP recovered more quickly than MQR (Figure 4-2). By 1987, both were progressing towards normal (reference) OSI levels. The June 1991 survey documented the radical shift of OSIs at MQR stations. Finally, Hurricane Bob and the "Halloween" storm of 1991, both of which occurred after the 1991 CLIS survey, did not prevent the recolonization documented in the 1992 survey.

It is apparent that MQR has cycled through several stages of stress and recovery, and that the recovery has been slower than at other CLIS mounds. The current state of MQR, improved since 1991 but still below reference, is a result of the decrease of habitat quality observed between the 1987 and 1991 REMOTS® surveys. A smaller scale decrease in OSI values also occurred at CS-1 (from 11 to 7) during the same time interval (Figure 4-1). The cause of the stress recorded at MQR during this time period is crucial to understanding recolonization factors at MQR.

4.3 Recolonization Factors at MQR

Factors affecting habitat quality and postdisturbance recolonization are either chemical or physical or both. Previous explanations of the slow benthic recolonization at MQR have been chemical, including the presence of hypoxic water, a high organic content of MQR sediments, and elevated levels of sediment contaminants (SAIC 1990a, Murray 1992). Physical factors which may be responsible for benthic disturbance include both large-scale and small-scale processes. Large-scale events include storms as in the obvious case of Hurricane Gloria (SAIC 1989b); these events should affect all of the mounds at CLIS, as well as the CLIS reference areas. Small-scale disturbances include biological (macrofauna) and anthropogenic (trawling, etc.) sources. Both of these types of small-scale disturbances could occur within individual mounds.

It is clear that both the concentrations of contaminants and the content of organic carbon in the sediments at MQR are higher than at other capped CLIS mounds. High organic carbon would be expected to ameliorate contaminant effects, to some extent, by "removing" or binding contaminants so that they are not as available to biota. Results from a recent coring study at MQR indicated that the capping material at MQR does contain relatively high levels of polyaromatic hydrocarbons (PAHs) (Murray 1992). The presence of methane in REMOTS® pictures as recent as the present survey indicates that relatively high concentrations of organic carbon remain in the MQR sediments. However, the pattern of recolonization determined from the sequence of OSIs at MQR suggests that recolonization does occur, despite the potential stress associated with contaminated sediments.

The key question for MQR is the dramatic drop of OSIs which occurred in the time interval between the 1987 and 1991 REMOTS® surveys. This sharp, localized decrease suggests a physical cause (such as trawling), perhaps exacerbated by adverse chemical conditions. The presence of numerous mud clasts and rip-ups, and evidence of surface erosion in the REMOTS® photographs of the 1991 survey support this conclusion. Additionally, since this decrease in OSI values is not widespread among the mounds at CLIS, the cause of the stress must be localized physical disturbance.

5.0 SUMMARY AND RECOMMENDATIONS

- Routine monitoring at MQR has indicated a pattern of anomalous recolonization relative to other CLIS capped mounds. Historically, MQR has exhibited slow recolonization rates relative to other capped mounds at CLIS.

- MQR provides an excellent test case for the dredged material management protocols as described in the Tiered Monitoring Program created for the NED. It is the first mound to trigger higher tiers of monitoring and testing, under the tiered monitoring framework. Following these tiered protocols, several monitoring surveys, including REMOTS® work and sediment sampling, have been conducted at MQR.

- A reconnaissance REMOTS® and bioassay survey in 1991 showed a substantial regression of benthic environmental parameters since the previous survey in 1987, which suggested a small-scale physical disturbance.

- Results from the 1992 REMOTS® survey at CLIS showed a clear improvement of the habitat quality at MQR since the 1991 survey, although still anomalous relative to the CLIS reference area.

- The persistence of slow recolonization since the formation of MQR, together with sediment chemical results presented in an earlier report, indicate that MQR should be further capped, and monitoring should continue.

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APPENDIX

MQR REMOTS® DATA, AUGUST 1992

STATION NAME	REP	AVERAGE PENET.	BOUND. ROUGH.	BR TYPE	GR SZ MAJ MOD	GR SZ RANGE	RPD AVE	MUD CLAST	MC DIA.	MC STATUS	METH PRESENT	METH AVE	METH COUNT	DM PENET.
130E	a	14.38	0.26	Physical	> 4	3 to > 4	1.26	0	0	x	0	0	0	14.51
130E	b	14.83	-0.04	Physical	> 4	3 to > 4	0.4	3	0.43	Both	0	0	0	14.81
130E	c	14.32	0.98	Physical	> 4	3 to > 4	1.72	0	0	x	0	0	0	14.81
130N	a	14.87	0.98	Physical	> 4	1 to > 4	1.34	4	0.64	Oxidized	0	0	0	15.32
130N	b	13.68	0.72	Biological	> 4	2 to > 4	1.45	2	0.34	Oxidized	0	0	0	13.96
130N	c	14.89	1.19	Biological	> 4	2 to > 4	1	2	0.3	Both	0	0	0	15.4
130NE	a	15.11	0.85	Biological	> 4	1 to > 4	1.74	0	0	x	0	0	0	15.45
130NE	b	0	0	x		to	0	0	0	x	0	0	0	0
130NE	c	14.64	0.85	Biological	> 4	1 to > 4	1.34	1	0.74	Oxidized	0	0	0	15.11
130NW	a	14	0.85	Physical	3 to 4	2 to > 4	1.13	0	0	x	0	0	0	14.34
130NW	b	15.23	0.6	Physical	3 to 4	2 to > 4	0.79	0	0	x	0	0	0	15.53
130NW	c	15.23	0.43	Physical	3 to 4	2 to > 4	1.38	0	0	x	0	0	0	15.45
130S	a	17	0.47	Biological	3 to 4	2 to > 4	0.94	0	0	x	0	0	0	17.28
130S	b	14.19	0.47	Biological	> 4	2 to > 4	1.19	0	0	x	0	0	0	14.38
130S	c	16.17	0.17	Physical	3 to 4	2 to > 4	0.81	0	0	x	0	0	0	16.25
130SE	a	16.15	0.38	Biological	> 4	1 to > 4	2.08	0	0	x	0	0	0	16.3
130SE	b	16.15	0.38	Biological	> 4	2 to > 4	1.02	0	0	x	0	0	0	16.38
130SE	c	16.42	0.34	Biological	> 4	1 to > 4	0.94	0	0	x	0	0	0	16.51
130SW	a	16	0.94	Biological	> 4	0 to > 4	0.81	0	0	x	0	0	0	16.47
130SW	b	15.55	0.81	Biological	> 4	2 to > 4	1.02	0	0	x	0	0	0	15.96
130SW	c	14	0.68	Biological	> 4	0 to > 4	0.66	0	0	x	1	6.51	3	14.34
130W	a	15.02	0.94	Physical	3 to 4	2 to > 4	1.51	5	0.77	Both	0	0	0	15.06
130W	b	14.67	0.14	Physical	3 to 4	2 to > 4	2.08	4	0.6	Both	0	0	0	14.74
130W	c	15.11	0.26	Physical	3 to 4	2 to > 4	0.83	2	0.43	Oxidized	0	0	0	15.23
195E	a	14.34	0.43	Physical	3 to 4	2 to > 4	1.77	0	0	x	0	0	0	14.55
195E	b	15.93	0.26	Physical	> 4	3 to > 4	0.58	4	0.51	Oxidized	0	0	0	16.06
195E	c	15.87	0.34	Physical	3 to 4	2 to > 4	1.83	0	0	x	0	0	0	16.04
195N	a	16.76	0.6	Physical	> 4	2 to > 4	1.13	5	0.77	Oxidized	0	0	0	17.15
195N	b	16.93	0.43	Physical	3 to 4	2 to > 4	1.26	3	0.77	Oxidized	0	0	0	17.15
195N	c	16.74	0.21	Physical	3 to 4	2 to > 4	1.64	1	0.72	Oxidized	1	14.19	2	16.85

STATION NAME	REP	SUCCESSIONAL STAGE	LOW DO	OSI	DM > PENET.	LOW PENET.	SAND/ MUD	SHELL LAG	GENERAL COMMENTS
130E	a	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	
130E	b	Stage I	NO	2	DM > Pen	0	Sand/Mud	0	
130E	c	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	
130N	a	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm
130N	b	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm
130N	c	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm
130NE	a	Stage I ON Stage III	NO	8	DM > Pen	0	Sand/Mud	0	x
130NE	b	x	NO	99	0	Low Pen	0	0	not analyzed: pull-away or burrow opening that collapse
130NE	c	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	stage III questionable
130NW	a	Stage I	NO	3	0	0	Sand/Mud	0	shell material at surface relic dm
130NW	b	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	relic dm
130NW	c	Stage III	NO	7	DM > Pen	0	Sand/Mud	0	relic dm Stage III tube
130S	a	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	relic dm
130S	b	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	x
130S	c	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	relic dm rippled surface very small void
130SE	a	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	shell on surface
130SE	b	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	x
130SE	c	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	x
130SW	a	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	x
130SW	b	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	darker sediment fairly uniform rpd
130SW	c	Stage I ON Stage III	NO	4	DM > Pen	0	Sand/Mud	0	some shells on surface, patchy rpd, small void on right
130W	a	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	shell fragments
130W	b	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	x
130W	c	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm
195E	a	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	x
195E	b	Stage I	NO	2	DM > Pen	0	Sand/Mud	0	relic dm
195E	c	Stage I	NO	4	DM > Pen	0	Sand/Mud	Shell Lag	relic dm
195N	a	Stage I	NO	3	0	0	Sand/Mud	0	mud clasts relic dm
195N	b	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm
195N	c	Stage I ON Stage III	NO	6	DM > Pen	0	Sand/Mud	0	methane mud clasts relic dm

STATION NAME	REP	AVERAGE PENET.	BOUND. ROUGH.	BR TYPE	GR SZ MAJ MOD	GR SZ RANGE	RPD AVE	MUD CLAST	MC DIA.	MC STATUS	METH PRESENT	METH AVE	METH COUNT	DM PENET.
195S	a	15.76	1.15	Physical	> 4	2 to > 4	1.94	0	0	x	0	0	0	16.55
195S	b	15.83	0.43	Biological	> 4	1 to > 4	2.45	3	0.72	Oxidized	0	0	0	15.96
195S	c	16.15	1.06	Biological	> 4	2 to > 4	1.19	3	0.21	Oxidized	0	0	0	16.59
195W	a	16.28	1.23	Physical	3 to 4	3 to > 4	1.45	0	0	x	0	0	0	16.68
195W	b	15.11	0.51	Physical	3 to 4	2 to > 4	1.53	0	0	x	0	0	0	15.23
195W	c	14.7	0.21	Physical	3 to 4	1 to > 4	1.28	8	0.18	Oxidized	0	0	0	14.85
65E	a	12.87	0.72	Physical	> 4	3 to > 4	2.06	3	0.32	Oxidized	1	5.08	1	13.23
65E	b	13.64	0.04	Physical	3 to 4	2 to > 4	2.62	0	0	x	0	0	0	13.66
65E	c	14.11	0.38	Physical	3 to 4	3 to > 4	1.32	6	0.48	Oxidized	0	0	0	14.3
65N	a	13.15	1.19	Physical	> 4	2 to > 4	0.98	3	0.72	Oxidized	0	0	0	13.66
65N	b	13.83	0.51	Physical	3 to 4	2 to > 4	1.36	0	0	x	0	0	0	14
65N	c	14.19	0.38	Biological	3 to 4	2 to > 4	1.17	1	0.34	Oxidized	0	0	0	14.38
65NE	a	14.83	0.98	Biological	> 4	1 to > 4	0.55	0	0	x	0	0	0	15.23
65NE	b	14.34	0.77	Biological	> 4	1 to > 4	0.57	3	0.67	Both	0	0	0	14.55
65NE	c	14.08	0.51	Biological	> 4	1 to > 4	0.51	0	0	x	0	0	0	14.25
65NW	a	14.13	0.77	Indeterminate	> 4	2 to > 4	2.26	3	0.39	Oxidized	0	0	0	14.42
65NW	b	15.13	0.64	x	> 4	2 to > 4	2.11	0	0	x	0	0	0	15.45
65NW	c	15.81	0.47	Biological	> 4	2 to > 4	0.98	2	0.34	Reduced	0	0	0	16.04
65S	a	15.47	0.47	Biological	> 4	2 to > 4	1.02	0	0	x	1	10.66	1	15.62
65S	b	17.13	0.64	Biological	3 to 4	2 to > 4	1.34	2	0.34	Both	0	0	0	17.53
65S	c	17.51	0.13	Biological	> 4	2 to > 4	1.19	1	0.39	Oxidized	0	0	0	17.57
65SE	a	15.85	0.3	Physical	> 4	2 to > 4	0.94	3	0.39	Oxidized	0	0	0	16.04
65SE	b	14.98	0.43	Biological	> 4	2 to > 4	1.06	0	0	x	0	0	0	15.15
65SE	c	14.45	0.64	Indeterminate	> 4	1 to > 4	0.8	4	0.81	Oxidized	0	0	0	14.72
65SW	a	15.85	0.47	Biological	> 4	1 to > 4	1.64	0	0	x	0	0	0	16
65SW	b	15.36	0.17	Biological	> 4	2 to > 4	1.45	1	0.34	Oxidized	0	0	0	15.45
65SW	c	15.36	0.51	Biological	> 4	1 to > 4	0.91	0	0	x	0	0	0	15.45
65W	a	18.93	0.6	Physical	3 to 4	3 to > 4	1.47	0	0	x	1	12.53	10	19.23
65W	b	15.57	0.34	Physical	3 to 4	2 to > 4	1.55	0	0	x	0	0	0	15.74
65W	c	13.28	1.02	Physical	> 4	3 to > 4	2.28	0	0	x	0	0	0	13.79
CTR	a	16.02	0.38	Physical	3 to 4	2 to > 4	1.85	0	0	x	0	0	0	16.21
CTR	b	15.38	0.98	Physical	3 to 4	3 to > 4	1.51	4	0.39	Oxidized	1	10.4	2	15.87
CTR	c	15.57	0.17	Physical	3 to 4	2 to > 4	1.43	0	0	x	0	0	0	15.66

STATION NAME	REP	SUCCESSIONAL STAGE	LOW DO	OSI	DM > PENET.	LOW PENET.	SAND/ MUD	SHELL LAG	GENERAL COMMENTS
195S	a	Stage I ON Stage III	NO	8	DM > Pen	0	Sand/Mud	0	dm layer at surface, large burrow
195S	b	Stage I	NO	5	DM > Pen	0	Sand/Mud	0	relic dm
195S	c	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	relic dm, void?
195W	a	Stage I	NO	3	0	0	Sand/Mud	0	relic dm
195W	b	Stage I	NO	4	0	0	Sand/Mud	0	small shell fragments in the sand, relic dm
195W	c	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	small shell fragments in sand at surface, relic dm
65E	a	Stage I ON Stage III	NO	6	DM > Pen	0	0	0	
65E	b	Stage I ON Stage III	NO	9	DM > Pen	0	Sand/Mud	0	
65E	c	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm
65N	a	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm, patchy rpd
65N	b	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	relic dm
65N	c	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	relic dm, patchy rpd
65NE	a	Stage I ON Stage III	NO	6	DM > Pen	0	Sand/Mud	0	x
65NE	b	Stage I ON Stage III	NO	6	DM > Pen	0	Sand/Mud	0	some shells in upper sediment, patchy rpd
65NE	c	Stage I ON Stage III	NO	6	DM > Pen	0	Sand/Mud	0	x
65NW	a	Stage I	NO	5	DM > Pen	0	Sand/Mud	0	relic dm
65NW	b	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	x
65NW	c	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	x
65S	a	Stage I ON Stage III	NO	5	DM > Pen	0	Sand/Mud	0	relic dm
65S	b	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	maldanid tube? relic dm
65S	c	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	RELIC DM
65SE	a	Stage III	NO	7	DM > Pen	0	Sand/Mud	0	patchy rpd, darker sediment here, voids and burrow
65SE	b	Stage I ON Stage III	NO	7	DM > Pen	0	Sand/Mud	0	maldanid tube?
65SE	c	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	patchy rpd
65SW	a	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	x
65SW	b	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	Stage III relic
65SW	c	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	x
65W	a	Stage I	NO	1	DM > Pen	0	Sand/Mud	0	relic dm
65W	b	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	x
65W	c	Stage III	NO	9	DM > Pen	0	0	0	juvenile nephtys
CTR	a	Stage I	NO	4	DM > Pen	0	Sand/Mud	0	relic dm
CTR	b	Stage I	NO	2	DM > Pen	0	Sand/Mud	0	shell frags
CTR	c	Stage I	NO	3	DM > Pen	0	Sand/Mud	0	