Response to USEPA Questions
Commonwealth of Massachusetts
March 20, 2013
New Bedford Marine Commerce Terminal (NBMCT)

Introduction

Thank you for this opportunity to provide USEPA additional information related to the development of the NBMCT. Development of this facility represents an important opportunity to deliver lasting environmental benefits to the New Bedford region, as well as accelerate economic development throughout the region.

This document provides responses to some of the USEPA's comments and requests for information that were the subject of an e-mail dated March 14, 2013.

The format of the document will first list a request by the Commonwealth, and will then follow a comment–and-response outline, where each of the USEPA Comments will be listed in the order in which they were presented in the USEPA's Memoranda with the Commonwealths Response to each Comment presented immediately thereafter.

Commonwealth Request

Item 1: The Commonwealth has noted that EPA has required that the following two plans be submitted thirty (30) days before land and water activities take place: the Contingency Plan and the Contractor Work Plan for PCB Remediation Work. As these two documents need to be completed by the Contractor for the NBMCT, the Commonwealth requests an extension in the time granted by EPA for submission and/or an accelerated review process for these plans, if an extension is not possible.

Response to EPA Questions/Comments

Comment 1: Need a written request to reconsider inclusion of blasting in the Project due to new information (acoustical studies and Corps determination); blasting would be a method of last resort, to be utilized only if the other methods of rock removal are not successful or feasible due to site conditions. EPA will promptly re-initiate consultation with NMFS regarding impact of blasting on the Atlantic sturgeon. This will involve EPA sending a

SDMS Doc ID 540361

biological assessment to NMFS and requesting concurrence in EPA's determination regarding the potential for effects on the Atlantic sturgeon. NMFS has committed to respond promptly. EPA will also consult, pursuant to EFH, with NMFS about impacts to other species from blasting.

Response: The written request for inclusion of blasting will be submitted to EPA under separate cover.

Comment 2: EPA needs to see positive confirmation test of the fish detection system well before any work in water commences. This may be satisfied by a literature demonstration. However, if supporting literature is not available, the Commonwealth needs to take undertake demonstration project to show that fish detection system works and that fish are not entering the closed area.

Response: In response to the EPA's request for a literature review of the fish survey methodology utilized during fish monitoring surveys for the New Bedford Marine Commerce Terminal project, Apex has conducted research of readily available literature to support the validity of scuba diver and underwater video camera transects for surveys of both flatfish and finfish. The Commonwealth is currently conducting diver and video surveys, and the following are examples of previously completed projects which successfully utilized similar methodologies for the surveying of fish in comparable environments.

Massachusetts Water Resources Authority and Outfall monitoring project [Coats, Douglas A., Imamura, Eiji, Campbell, James F. (1995)]:
This project was conducted within Massachusetts Bay using a remotely operated vehicle (ROV) to characterize marine life around a diffuser cap corridor at the end of and outfall. Transects were divided into 50 meter subsections and the surveys largely were conducted at water depths less than 30 meters. During the survey periods over eight hours of color video was collected, these results showed presence of both finfish such as haddock and cod with moderate accuracy, and flatfish such as winter flounder with a high level of accuracy. The results of this project proves that video transects are a good method in quantifying many different fish species in the survey area.

A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers [Spencer M.L., Stoner A.W., Ryer C.H., Munk E.J. (2005).]:

A project was conducted in 2002 in which utilized cameras for surveying flatfish was conducted in Yaquina Bay, Oregon, and in bays of Kodiak Island, Alaska. During this project a sled mounted camera was towed behind a 3 meter long skiff along transect lines for quantifying juvenile flatfish in these areas. Two sleds were used, one had a tickling chain on it and the other did not. Parallel surveys were also done with diver swims and beam trawls over the same areas. Utilizing the camera sled with chain method, it was found that juvenile flatfish density estimates were equivalent or exceeded the results from the other survey methods. The video sled without chain also was successful in recording the flatfish but with a lesser density than the sled with the chain. It is also noted that a tickler chain made no appreciable difference in seeing flatfish which were noted as 1 year or older. The results found that the video sled and diver swim transect methods were most accurate in quantifying flatfish.

Population estimates of Pacific coast groundfishes from video transects and swept-area trawls [Adams B. Peter, *et al* (1995)]:

A study was done in 1995 off the central California coast to compare video transects to trawls in population estimates of demersal fish. An ROV mounted camera system was compared directly to swept-area trawl abundance estimates. For benthic fishes the ROV method not only yielded higher species estimates, but also had a much lower coefficient of variation than did the trawl method. The results show that both methods are valid for fish population density surveying, but the ROV method was much better at estimating skates and flatfish, or any other small or round shaped bottom dwelling fishes.

Nearshore Marine Biological Survey and Assessment Pinellas County Share Protection Project Comprehensive Borrow Area Study [Dial Cordy and Associates, Inc. (2002).]:

In 2002 the U.S. Army Corps of Engineers did a marine biological survey and assessment of the of the Pinellas County shore line in central Florida. Because of the shoreline erosion and lowered beach profiles caused by the forces of nature in this area, these areas were evaluated for occurrence and quality of the marine habitats. To identify marine resources an ROV with a video camera was used running transects at 100-foot intervals over 160 nautical miles of transect lines. Diver characterizations were used as supplements to the video survey for identifying corals and algae. During these surveys a total of 22 species from 16 families were observed, mostly including small demersal fish but also pelagic species as well.

An Assessment of the Abundance and Species Composition of Dominican Reef Fishes [Green, Dillon M. (2002)]:

In 2002 a study was done in Dominica to qualify and quantify reef fishes at 8 survey sites off the western coastline of Dominica using roving diver fish survey techniques. Scuba divers and snorkelers were used to visually observe fish species and record their findings with a number scale which was later entered into Microsoft Excel and analyzed. The results showed 115 different fish species were observed, and abundance data was collected for 87 species. The study was successful in documenting various species and it was found that belt transects would be more accurate in determining population densities than random rover dive surveying.

The following is a Bibliography of Literature Examined including the five summarized above (and also included within **Attachment A**):

- Adams B. Peter, *et al* (1995). Population estimates of Pacific coast groundfishes from video transects and swept-area trawls. Fishery Bulletin 93:446-455 (1995).
- Coats, Douglas A., Imamura, Eiji, Campbell, James F. (1995). Hard-Substrate Reconnaissance Survey S9404 Final Analysis Report. Massachusetts Water Resources Authority, Environmental Quality Department Technical Report Series No. 95-1.
- Dial Cordy and Associates, Inc. (2002). Nearshore Marine Biological Survey and Assessment Pinellas County Share Protection Project Comprehensive Borrow Area Study. Prepared for U.S. Army Corps of Engineers, Jacksonville District, Jacksonville Florida.
- Green, Dillon M. (2002). Dominica Reef Fish Status 2002: An Assessment of the Abundance and Species Composition of Dominican Reef Fishes. Institute for Tropical Marine Ecology Inc. ITME Research report – Number 13.
- Hollingsworth. Lea (04/21/2008). Digital Camera Transects. In Coral Reef Assessment and Monitoring Program Hawaii. . Retrieved 3/7/2013, from http://cramp.wcc.hawaii.edu/LT_Montoring_files/lt_digital_camera_transects.htm.
- Messing, Charles G. *et al* (2006). Calypso LNG Deepwater Port Project, Florida Marine Benthic Video Survey. National Coral Reef Institute, Nova Southeastern University Oceanographic Center 8000 North Ocean Drive, Dania Beach, FL 33004. Submitted to: Ecology and Environment, Inc. & SUEZ Energy North America, Inc.
- Palka, Debbie (1991). Abundance Estimate of the Gulf of Maine Harbor Porpoise. NOAA/NMFS, Northeast Fisheries Science Center, Woods Hole, MA 02543.
- Schmitt, E.F., Sluka, R.D., Sullivan- Sealey, K.M. (2002). Evaluating the use of roving diver and transect surveys to assess the coral reef fish assemblage off southeastern Hispaniola. Coral Reefs (2002(21: 216-223.

- Spencer M.L., Stoner A.W., Ryer C.H., Munk E.J. (2005). A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers. Estuarine, Coastal and Shelf Science 64 (2005) 497-503.

Additionally, the Commonwealth has contacted It's subcontractor to provide documentation of fin and flat fish species encountered during similar underwater resource mapping and survey activities that the subcontractor has completed utilizing diver or towed camera techniques. The subcontractor (Fathom Research LLC.) has looked through their library of past surveys where similar methodologies were utilized and provided a small sample of captured underwater images. Attached (included as **Attachment A**) are the provided sample photographs from a resource survey conducted near the Town of Oak Bluffs, Massachusetts, where juvenile fish are clearly visible and relatively unaffected by the presence of the diver and equipment. Additional information, including video survey data collected by Fathom Research from other Southern New England harbors can be made available to the U.S. EPA if necessary.

Comment 3: Regarding the timing of blasting, assuming it will occur after June, the Commonwealth seems to be willing to leave the silt curtains in place until the rock is removed via blasting or some other means. Of course, if at some point after the fish window is closed and it becomes clear that blasting is not necessary, then the fish deterrent system can be removed.

Response: The Commonwealth wishes to clarify its understanding of previous conversations with EPA regarding fish deterrence during blasting. EPA had requested that the Commonwealth consider keeping the Fish Deterrent System in place past June 15, 2013 in order to be protective of fish resources during blasting activities. The Commonwealth undertook a comprehensive evaluation of EPA's request, and due to significant cost and logistical issues associated with recreational boating in New Bedford Harbor during the summer months, the Commonwealth believes that it is prudent to remove the Fish Deterrent System as of June 15, 2013. However, Section 02900 – BLASTING, of the Commonwealth's specifications, stipulate the use of the following means to minimize the impacts to fish resources, many of which are very similar in intent and implementation to the full Fish Deterrent System:

- Contractor shall enclose blast areas with silt curtains and bubble curtains to keep fish species away from the blast area and minimize the pressure wave and turbidity generated from blasting.
- Contractor shall use non-explosive noise techniques to move fish and marine mammals from the immediate blast zone.

- Stemming, in which rock is placed into the top of the borehole to damp the shock wave reaching the water column, thereby reducing fish mortalities from blasting, shall be utilized.
- All blasting operations shall take place utilizing sonar to identify fish schools and with a fisheries observer (hired by the Contractor) who is approved by the Massachusetts Division of Marine Fisheries (and National Marine Fisheries Services) in attendance. The fisheries observer shall observe for fish mortality.
- There shall be no blasting during the passage of schools of fish or when a marine mammal is present as determined by the fisheries observer.
- Blasting shall be conducted with a fish startle system.

The Commonwealth anticipates that these requirements will be sufficiently protective of fish resources and will therefore not require that the Fish Deterrent System be kept in place past June 15, 2013.

Comment 4: 200' Length Extension of the Deep-Draft Berthing Area - A modification to the existing TSCA Determination will be necessary. Need additional information from Commonwealth on: depth, location, concentrations, sampling, map, where disposed. Further conversation needed with Apex to work out details.

Response: An additional drawing requested by EPA, including a plan with close-up sections and a cross-section of the work, is attached as **Attachment B**. Please note that the previous analytical data generated during characterization of the marine areas of the New Bedford Marine Commerce terminal are applicable for the 200 foot length extension.

The volumes generated during implementation of the deep-draft 200 foot expansion to the north are consistent with those noted within Table 1 of the EPA Final Determination (2,500 cubic yards of contaminated sediment and 8,000 cubic yards of clean sediment). The contaminated sediment generated during expansion will be placed within CAD Cell #3. Clean materials generated during expansion will be utilized within the Main Facility Parcels, as outlined within Table 1 of the Final Determination. Material that cannot be utilized within the Main Facility Parcels may be disposed of offsite.

Comment 5: 50' Width Expansion of Channel - A modification to the existing TSCA Determination will be necessary. Need additional information from Commonwealth on: depth, location, concentrations, sampling, map, where disposed. Further conversation needed with Apex to work out details.

Response: An additional drawing requested by EPA, a plan with close-up sections and cross-sections of the work, is attached as **Attachment C**. Please note that the previous analytical data generated during characterization of the marine areas of the New Bedford Marine Commerce terminal are applicable for the southern portion of the 50 foot width channel expansion (the portion south of the Federal Turning Basin). Please also note that previous analytical data generated in the Federal Turning Basin was collected by USEPA and USACE when characterizing the area for the New Bedford Superfund Site and the Federal Maintenance Dredging; therefore, the Commonwealth believes that this data is adequately representative of both the existing 175 foot wide channel, and the proposed 50 foot expansion.

It is currently anticipated that the contaminated sediment generated during construction of this alternative would be consistent with the volumes listed within Table 1 from the Final Determination (8,500 cubic yards); however, since the revised 50 foot expansion would be moved to the west, which has existing elevations deeper than those to the east, a reduction in the generation of clean sediment is anticipated: from 13,500 cubic yards of clean material (currently listed within Table 1) to approximately 7,000 cubic yards. The contaminated materials generated during expansion will be placed within CAD Cell #3. Clean materials generated during expansion will be utilized within the Main Facility Parcels, as outlined within Table 1 of the Final Determination. Material that cannot be utilized within the Main Facility Parcels may be disposed of offsite.

Comment 6: CAD Expansion - Assuming disposal into CAD 3, need written information and map of additional expansion of CAD 3 that is necessary to accommodate the additional work. Need additional amount of dredging required, additional acreage needed, any increase in depth and where contaminated sediment will be disposed. Need confirmation that there is sufficient capacity in receiving area to accommodate the additional dredging.
Need confirmation that there is adequate data to demonstrate that the additional material to be removed as part of CAD 3 expansion contains sediment with PCB concentrations of less than 50 ppm.

Response: No expansion of CAD #3 is requested by the Commonwealth at this time. It is currently anticipated that the material volumes to be generated while dredging the deep-draft expansion of 200 feet to the north and the increased 50 foot width of the channel may be disposed of within CAD Cell #3 without further expansion of the CAD Cell #3 shown within the Commonwealth's December 5, 2012 design drawings. The added capacity is anticipated to be generated by self-compression of sediments within CAD Cell #3. This self-compression was not

previously accounted for, and served as a "factor of safety" should additional volumes be generated during construction.

However, as USEPA has noted in prior communications, the Commonwealth increased the dredge depth of CAD Cell #3 during the re-design conducted by the Commonwealth prior to its issuance of its December 5, 2012 design drawings from -45 MLLW to -60 MLLW. Although a CAD Cell #3 depth of -60 MLLW was not explicitly approved within EPA's Final Determination, page 29 of the Final Determination states "the clean glacial sand will be dredged down to 45 feet below the existing harbor floor". As the existing harbor floor in the area of construction of CAD Cell #3 ranges from -6 MLLW to -15 MLLW, "45 feet below the existing harbor floor" is an elevation that ranges from -51 MLLW to -60 MLLW.

The intent of this depth change was to keep the areal impact of CAD Cell #3 to a minimum during the re-design. As a result, the design size of CAD Cell #3 is 8.29 acres, which is significantly less than the 8.76 acres permitted within the Final Determination. Although the Commonwealth believes that the redesign of CAD Cell #3 was consistent with the text of the Final Determination as noted above, if EPA believes that a change to the Final Determination is required to accommodate the deeper depth of CAD Cell #3, the Commonwealth requests that EPA approve a change in the depth of CAD Cell #3 to -60 MLLW.

Although the Commonwealth does not anticipate any further increase in the area of CAD Cell #3 at this time; the Commonwealth requests that the maximum area of CAD Cell #3 remain at 8.76 acres, in case any future adjustments are required during the construction process.

Comment 7: Site Control - Radio Tower: Need written submission on steps to be taken to secure control of the property and a schedule for those steps. Hathaway: Need written submission on schedule for obtaining site control.

Response: The written submissions on site control will be submitted to EPA under separate cover.

Comment 8: River's End Park - A wetlands scientist with experience in salt marsh creation projects and invasive species control must be hired to oversee the entire mitigation project, not just planting; need identification of the name of the individual or firm that the Commonwealth intends to hire.

Response: The Commonwealth intends to hire Beals and Thomas, Inc., the firm that designed the River's End Mitigation Area, out of Plymouth Massachusetts, to oversee construction of the

mitigation area. Beals and Thomas will assign Stacy H. Minihane, PWS to oversee the project (see **Attachment D** for Beals and Thomas's qualifications and Ms. Minihane's resume).

Comment 9: Need detailed explanation of how the Commonwealth intends to implement the mitigation plan, including identification of whom it intends to retain to do the construction and a detailed schedule, for our review before finalizing any plans or contracts.

Response: The Commonwealth currently anticipates utilizing its construction contractor for the New Bedford Marine Commerce Terminal to construct the Winter Flounder Mitigation Area and the OU-3 Capping Mitigation Area. Construction of the Winter Flounder Mitigation Area is currently anticipated to take place approximately 3 months from the start of construction, and last approximately 4 months. Construction of the OU-3 Mitigation Area is currently anticipated to begin approximately 6 months from the start of construction and to last approximately 5 months.

The City of New Bedford through its Department of Public Infrastructure (DPI) has offered its resources to the Commonwealth to assist in construction of the River's End Mitigation Area. It is currently anticipated that DPI could be utilized for site work activities (although it is also possible that the Commonwealth may competitively bid the work, as shown on the schedule included as **Attachment E**). A separate contractor would be solicited for planting.

At present, the Commonwealth anticipates that DPI (if a separate contractor was not solicited) would conduct installation of erosion protection measures, site clearing, excavation, grading, stockpile management, installation of temporary site stabilization measures (erosion control blankets and coir rolls), and implementation of and transportation and offsite disposal of soil/sediment excavated during the work. DPI's (or the solicited contractor's) work would be overseen by Beals & Thomas, and site survey work would be utilized to confirm that the grades shown on the plans were achieved in the field.

If the City of New Bedford DPI were utilized, a separate contractor, one who specializes in wetland mitigation/planting, would then be utilized to install the wetland plantings. As the grading portion of wetland mitigation projects often does not exactly coincide with the planting portion of such projects, coordination of such a separate contractor would likely be easy to implement. The Commonwealth does not wish to name a specific contractor that has not yet been procured; however, some potential candidates for this work would include: SumCo Eco-Contracting or New England Environmental, Inc.

It is currently anticipated that the site work for the River's End Mitigation Area would begin in the summer of 2013 and last for approximately 5 months. Plantings would then take place either in the late fall of 2013 or early spring of 2014 (just after the thaw).

Funding for shellfish restoration activities will begin once a Notice to Proceed has been issued for the project. It is currently anticipated that MassDMF will obtain seed for the first growth of quahogs soon thereafter and will begin to grow-out the seed at their John Hughes Hatchery on Martha's Vineyard. It is currently anticipated that the first crop of shellfish will not be fully grown-out for at least nine to twelve months, after which they will be outplanted within the conditionally acceptable shellfish areas within Area II of the City of New Bedford, as outlined within the Final Mitigation Plan.

Tern surveys as outlined within the Final Mitigation Plan are currently anticipated to be conducted during 2013, beginning in mid-to-late April of 2013 and ending in mid-to-late August of 2013. Tern surveys will be conducted by a subcontracted avian biologist (the subcontract for which is not yet finalized) and will be conducted on equipment (vessels) that will otherwise be utilized to monitor construction activity (conduct bathymetric surveys and collect water quality samples).

A schedule for the overall mitigation project is included as **Attachment E**.

Comment 10: Need early coordination with EPA on draft construction and performance bonds, site protection instruments, conservation restriction, escrow accounts, etc. for the Rivers' End Park and OU3 mitigation activities. No bond, conservation restriction, etc. may be finalized until after receipt of EPA's comments on the drafts, and the final versions must be consistent with those comments, as specified in the special condition of Appendix E of the Final determination.

Response: Agreed. Coordination is on going with the EPA. EPA is currently reviewing the bond language. We expect to reach agreement on final language of each document, and then make the requested revisions for the finalized versions. The Commonwealth requests that EPA act with all speed on these items, as the Commonwealth must finalize the language with the City of New Bedford as well (since the City is a counterparty to the agreements), after which the City Council of the City of New Bedford must vote to agree to the final terms.

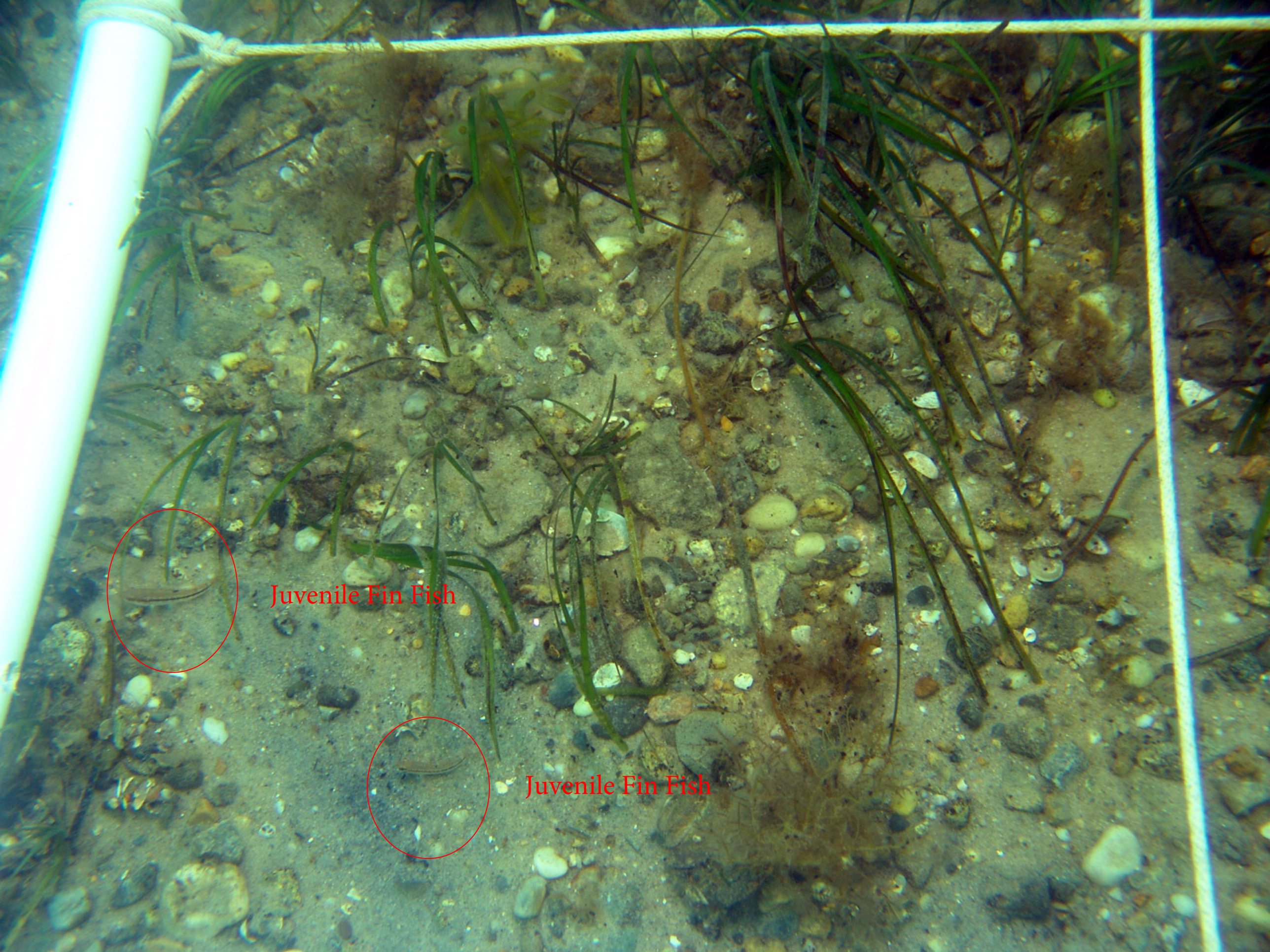
Comment 11: For shellfish restoration, the oyster reef was not authorized by the Final Determination; if it is to be included, a plan must be provided to EPA for review and approval before such work may proceed.

Response: Whether the oyster reef option will to be used for mitigation has yet to be determined. If the oyster reef is to be included, then the Final Determination may be updated at that time.

Comment 12: SER Project Manager - Need the name of the SER Project Manager; it was formerly Paul Craffey.

Response: MassDEP is currently in the process of selecting a SER Project Manager.

ATTACHMENT A


Juvenile Fin Fish
Juvenile Fin Fish

Juvenile Fin Fish -

Juvenile Fin Fish -

Population estimates of Pacific coast groundfishes from video transects and swept-area trawls

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Abstract.—Demersal fish surveys are used for two purposes: to detect trends in multispecies communities for environmental assessment and to provide fishery independent stock assessments for management. We compared remotely operated vehicle (ROV) and swept-area trawl surveys to evaluate their strengths and weaknesses for these two purposes. ROV abundance estimates tended to be higher and have lower coefficients of variation than did trawl abundance estimates. This trend is greatest for benthic species and particularly so for small, cylindrically shaped fishes. For patchily distributed, off-bottom fishes such as rockfish, *Sebastes* spp., sablefish, *Anoplopoma fimbria*, and Pacific whiting, *Merluccius productus*, the results vary between ROV and trawl estimates. For environmental assessment, the ROV estimates are superior because, for most species, abundances are higher and smaller changes can be detected. For fisheries management of commercially important species, the results are divided. Dover sole, *Microstomus pacificus*, and thornyheads, *Sebastolobus* spp., have higher ROV abundance estimates and lower coefficients of variation than the trawl. Sablefish, which exhibit more off-bottom behavior, have higher trawl estimates at two of three depths. The ROV and trawl provide different types of information not available from other gear. Much of the difference between the two types of surveys stems from the nature of the sampling gear and from the behavior, body shape, and size of the fishes.

Manuscript accepted 13 February 1995.
Fishery Bulletin 93:446–455 (1995).

Estimates of population abundance are essential to research for understanding the impact of human activities on marine demersal fish populations. Traditionally, swept-area trawl surveys have been used to obtain abundance estimates aimed at fisheries management. Recently, environmental surveys, used to monitor the impacts of pollution and coastal development, have become more widespread and important. These two types of surveys have different goals. Data from fisheries surveys are used as input for predictive models to forecast the results of alternative fisheries management strategies and are usually directed toward either a single species or a small species group. Environmental surveys are used to detect trends in populations over time, to distinguish those trends from natural variation, and are usually directed at an entire multispecies fish community.

Both types of survey population estimates are subject to the problems of bias and precision. Bias is a particular problem for fisheries surveys. Fishery stock assessment is based on models that integrate fishery catch-at-age data with fishery-independent survey estimates of abundance (Deriso et al., 1985). The catch-at-age data, sampled from the commercial fishery, document the trend of population change resulting from recruitment of young fish into the population and from removal of individuals out of the population due to fishing and natural mortality. The fishery-independent survey data are used as a measure of either relative or absolute abundance (Doubleday and Rivard, 1981). These survey data are used to calibrate or "tune" the trend ob-

tained from the catch-at-age data to determine how close the population is to a threshold value of overfishing (Kimura, 1989). Survey data also yield valuable information on migration routes, or biological parameters such as age-at-maturity, fecundity, and feeding. Biased survey estimates can result in very precise estimates of population abundance which are either lower or higher than the true population abundance.

For environmental surveys, the problem of precision is the major concern. Here, the goal is to detect a trend in population size, often of all the fish in the habitat, and to distinguish that trend from natural variation in fish populations. Abundance estimates from trawl surveys tend to have very large variances; often means and variances are correlated (see Lenarz and Adams, 1980). Resulting confidence intervals around means range from 50 to 100% for flatfish species and are greater than 100% for rockfish, *Sebastes* spp. (Raymore and Weinberg, 1990). As a result, all but the most extreme changes in population size are masked by these large confidence intervals. Methods commonly used to deal with this variability are transformations using the negative binomial (Lenarz and Adams, 1980) or the Delta distribution (Pennington, 1986). Data transformed by using these distributions often result in the variance being independent of the mean; however, the large confidence intervals and low statistical power remain.

In this study we examined video transects conducted from a remotely operated vehicle (ROV) as an alternative method for making population estimates of demersal fishes and compared these estimates to those from a conventional swept-area trawl survey.

Methods

Study site

The study site off central California lies along a cone-shaped ridge which runs southwest from Santa Cruz, California, and separates Monterey Canyon to the south from Ascension Canyon to the north (Fig. 1). Surface topography of the ridge is smooth and relatively unbroken (Greene[1]). The ridge is composed of sandstone, is covered with mud of pelagic origin, and is characterized by occasional areas of exposed bedrock. The stations where ROV and trawl operations were conducted were located along the ridge at depths of 200, 400, and 600 m (see Fig. 1).

[1] Greene, G. U.S. Geological Service, Pacific Marine Geology, 345 Middlefield Rd., Menlo Park, CA 94025. Personal commun., 1992.

ROV operations

ROV operations were conducted by using the Monterey Bay Aquarium Research Institute's ROV *Ventana* aboard the RV *Point Lobos*. The ROV was equipped with a Sony DXC-3000 video camera with a 5.5–44 mm zoom lens, illuminated by four 400-W sodium scandium lights. The zoom lens was used only for identification off the transect. Fiber-optic cable was used for viewing and recording images. The ROV was also equipped with a combined dual signal, a global positioning system and sonar system, which recorded the ROV position every 10 seconds. Depth, altitude off bottom, and various camera settings were also recorded.

At least three replicate transects were made at each depth. Transects at the 200-m, 400-m, and 600-m depths were sampled (for dates, see Table 1). Because a video transect covering the same total area as a trawl was not practical, a transect length of similar distance covered by a trawl was chosen (approximately 1.8 km or 1 nmi). Strip transects were used rather than line transects because the orientation of the lights produced a very sharp boundary between illuminated width of the transect and the darkness (Burnham et al., 1980; Butler et al., 1991). Transects were made at a speed of approximately 1.8 km/hr (1 knot) parallel to the isobath, interrupted occasionally by stops for fish identification or vehicle maintenance. Transects were made with a camera angle of 30° off the parallel horizon to the bottom and with a camera height averaging 0.7 m off the bottom. Fish were identified from videotapes by two independent viewers, and the response of each fish to the ROV was recorded as follows: 1) strongly attracted (rapidly moving into the frame); 2) weakly attracted

Table 1

Dates of remotely operated vehicle (ROV) and trawl sampling cruises at 200-m, 400-m, and 600-m depth strata off central California. The number in parentheses is the number of transects or trawls occurring during that month.

Depth stratum (m)	ROV	Trawl
200	Oct 1991 (3)	Apr 1991 (2)
		Sep 1991 (3)
		Jan 1992 (3)
400	Mar 1991 (1)	Apr 1991 (1)
	Oct 1991 (1)	Sep 1991 (3)
	Oct 1992 (2)	Jan 1992 (4)
600	Jul 1991 (1)	Apr 1991 (2)
	Sep 1991 (2)	Sep 1991 (4)
		Jan 1992 (3)

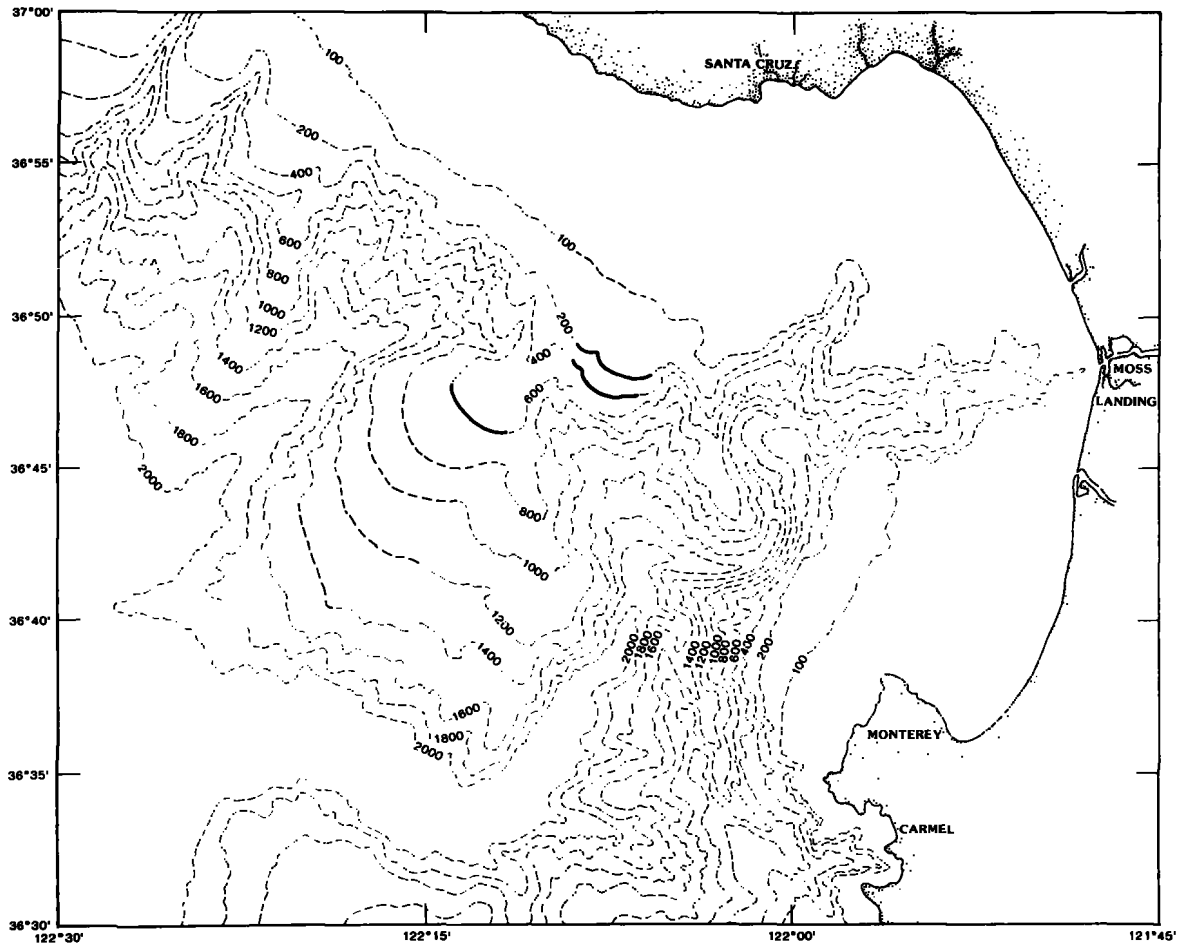

Figure 1

Study site off central California marked for 200-m, 400-m, and 600-m depth comparisons of population estimates from video transects conducted from an ROV survey and from swept-area trawl surveys.

(slowly moving into the frame); 3) no response (no movement); 4) weakly avoided (slowly moving out of the frame); and 5) strongly avoided (rapidly moving out of the frame). A time line, at which the fish were counted, was chosen in the center of the viewing area. To determine transect width at the time line, the ROV was transected over a 5-m square grid, and known lengths from the grid were measured on the monitor. From these lengths and standard photometric equations (Wakefield and Genin, 1987), the transect width was calculated to be 1.8 m (see Fig. 2). The vertical perspective of the video ranged from a height of 0.7 m at the camera to a visual horizon of 2.4 m in front of the ROV. The number of fish per transect was converted to fish per hectare by dividing the number of fish observed by the area covered (transect distance multiplied by transect width).

Trawl operations

Trawling was conducted on separate cruises on the RV *David Starr Jordan*. Three trawl surveys were conducted and a sample size of at least three trawls per station was taken per cruise (for dates, see Table 1). During the April 1991 cruise, all three replicates were not completed owing to inclement weather. Parallel tows were made along the same isobath as the ROV transect at a speed of approximately 3.7 km/hr (2 knots) for 30 minutes, although control of the trawl was not as exact as that of the ROV. The net, an Aberdeen high-rise trawl net with a 29-m (96-ft) headrope, was equipped with 1.5 × 2.1 m steel doors. Trawl openings were not measured; this type of trawl has an average horizontal opening of 13.5 m (see Fig. 2) and an average vertical opening of 5.5 m

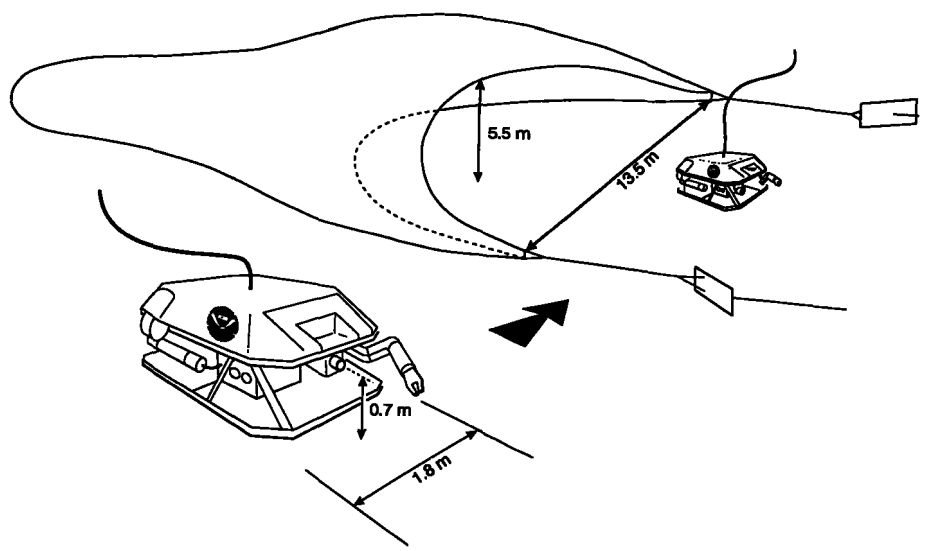

Figure 2
Sampling dimensions of a remotely operated vehicle (ROV) video transect and a trawl. Drawings of gear and sampling volumes are made to scale.

(Rose[2]). On deck, catches were handled with standard protocol (Smith and Bakkala, 1982) and were sorted to species, weighed, and measured. Lengths were measured for either a subsample of 100 fish or the entire catch, if it comprised less than 100 fish. When the catch was greater than 100 fish for a species, total species number was extrapolated from total species weight by using the average weight per fish from the subsample weight and numbers. Numbers of species per hectare were expanded by dividing the total species number by the area covered (distance traveled by a tow multiplied by the average width of the trawl).

Differences in ROV and trawl abundance estimates for individual species at each depth were tested by using t-tests for differences of unpaired log-transformed means. A sign test was used to determine whether the number of times that an ROV abundance estimate (or coefficient of variation) was higher than the trawl was greater than would have been expected randomly (i.e. a 50/50 ratio).

Statistical power is defined as $1-\beta$, where β is the probability of failing to reject a hypothesis when it is false, and therefore power is the probability of correctly rejecting a false hypothesis (Peterman, 1990).

[2] Rose, C. National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA, 98115–0700. Personal commun., 1992.

The power of the ROV and trawl abundance estimates was evaluated by calculating the required sample size to detect a 50% reduction from the log-transformed mean abundance at a fixed level of α (0.05) and at a high level of power ($1-\beta$, 0.80). Comparisons were made for the commercially important species (Dover sole, *Microstomus pacificus*; thornyheads, *Sebastolobus* spp.; and sablefish, *Anoplopoma fimbria*) and for a group of other abundant taxa (catsharks, Scyliorhinidae; skates, Rajidae; and eelpouts, Zoarcidae) at the 400-m depth (the only depth where all of these taxa occurred in both the ROV and the trawl surveys).

Results

More fish per hectare were observed from the ROV than were captured in the trawl at the 400-m and 600-m depths, whereas more fish were captured in the trawl at the 200-m depth (Fig. 3). However, the differences in the log-transformed total ROV and trawl estimates were only significant at the 400-m and 600-m depths (400 m: t=5.50, P<0.001; 600 m: t=3.28, P=0.011) and not at the 200-m depth (200 m: t=0.32, P=0.713). Numbers captured in the trawl at the 200-m depth were higher owing to a single large catch of two species of rockfish in one trawl. The ROV estimates of fish numbers were higher for most individual species or taxonomic groups that occurred in

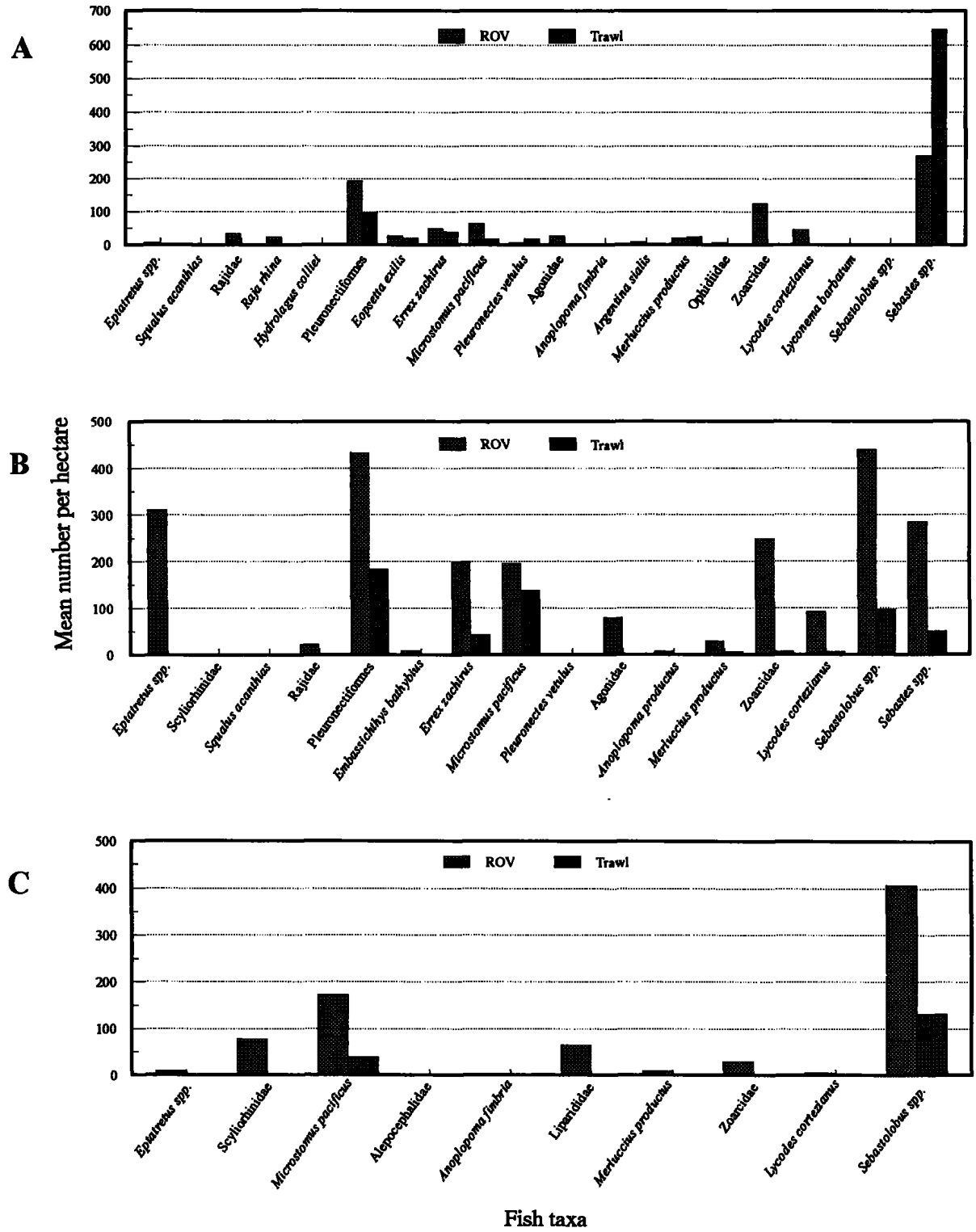

Figure 3

Mean numbers of fish per hectare estimated from an ROV video strip-transect survey and a swept-area trawl survey from (**A**) the 200-m depth station (ROV, n=3 and trawl, n=8); (**B**) the 400-m depth station (ROV, n=4 and trawl, n=8); and (**C**) the 600-m depth station (ROV, n=3 and trawl, n=9).

any abundance (greater than 1 fish/hectare in either estimate). For the 200-m, 400-m, and 600-m depths (Fig. 3), the mean ROV estimates were higher than the trawl estimates for 13 of 20, 15 of 16, and 9 of 10 comparisons, respectively (sign test 200 m: P=0.180; 400 m: P=0.001; and 600 m: P=0.011).

Especially large differences between the ROV and trawl estimates existed for strongly bottom-associated groups: skates, flatfish (Pleuronectiformes), and thornyheads, and particularly for small, cylindrically shaped fish that remained on the bottom: hagfish (*Eptatretus* spp.) poachers (Agonidae), and eelpouts. No significant differences were found between ROV and trawl estimates for fishes with more off-bottom behavior ("roundfish"), such as Pacific whiting, *Merluccius productus*, sablefish, and rockfish. Spiny dogfish, *Squalus acanthias,* were captured at every depth in low numbers in the trawls and were the only species to occur consistently in the trawls that were not seen with the ROV.

Coefficients of variation were generally smaller for the ROV estimates than for the trawl estimates. For species that occurred in both the ROV and the trawls, the coefficients were smaller for the ROV estimate in 10 of 15 comparisons at the 200-m depth, in 10 of 13 comparisons at the 400-m depth, and in 8 of 10 comparisons at the 600-m depth ([Fig. 4] sign test; 200 m: P=0.170; 400 m: P=0.050; and 600 m: P=0.050). ROV coefficients of variation were always larger for catsharks only and were mixed for Pacific whiting and some species of flatfish. At all depths, ROV coefficients of variation were smaller for rockfish and thornyheads, species typically with very large variances. Coefficients of variation for total fish number were much larger for the trawl estimates than for the ROV estimates at all depths (200-m, 2.4 times; 400-m, 4.6 times; and 600-m depths, 3.0 times).

The required sample sizes to detect a 50% reduction in the log-transformed means for a fixed level of power ($1-\beta$, 0.80) were smaller for the ROV than for the trawl, except for catsharks (Table 2). When the ROV sample sizes were smaller, the difference in sample sizes ranged from 1.3 to 19 times. For catsharks, a taxon with high variability, the ROV sample size was nearly six times larger than that for the trawls.

Most fishes showed no response to the ROV (Table 3). Considering all fish taxa observed, 80% showed no response to the ROV, 6% were attracted, and 14%

Table 2

The required sample size to detect a 50% reduction from the log-transform mean abundance of commercially important and abundant fish taxa at the 400-m depth from ROV and trawl surveys. The calculations were made at a fixed level of α (0.05) and power ($1-\beta$, 0.80).

	ROV	Trawl
Commercially important taxa		
Microstomus pacificus	5	95
Anoplopoma fimbria	25	55
Sebastolobus spp.	29	38
Abundant taxa		
Scyliorhinidae	251	43
Rajidae	9	104
Zoarcidae	14	90

Table 3

Response of commonly occurring fish taxa to the remotely operated vehicle (ROV). Fish from all depths (n=10) were recorded. Unid. = unidentified.

	Strongly attracted	Weakly attracted	No response	Weakly avoided	Strongly avoided
Eptatretus spp.	0	8	182	5	9
Scyliorhinidae	0	2	22	19	0
Rajidae unid.	0	2	42	4	8
Errex zachirus	0	1	89	3	26
Microstomus pacificus	0	3	326	10	21
Anoplopoma fimbria	0	4	5	2	2
Merluccius productus	0	45	28	11	7
Lycodes cortezianus	0	1	69	12	8
Sebastolobus spp.	0	2	173	8	10
Sebastes spp.	0	0	14	2	0
All taxa	0	68	950	76	91

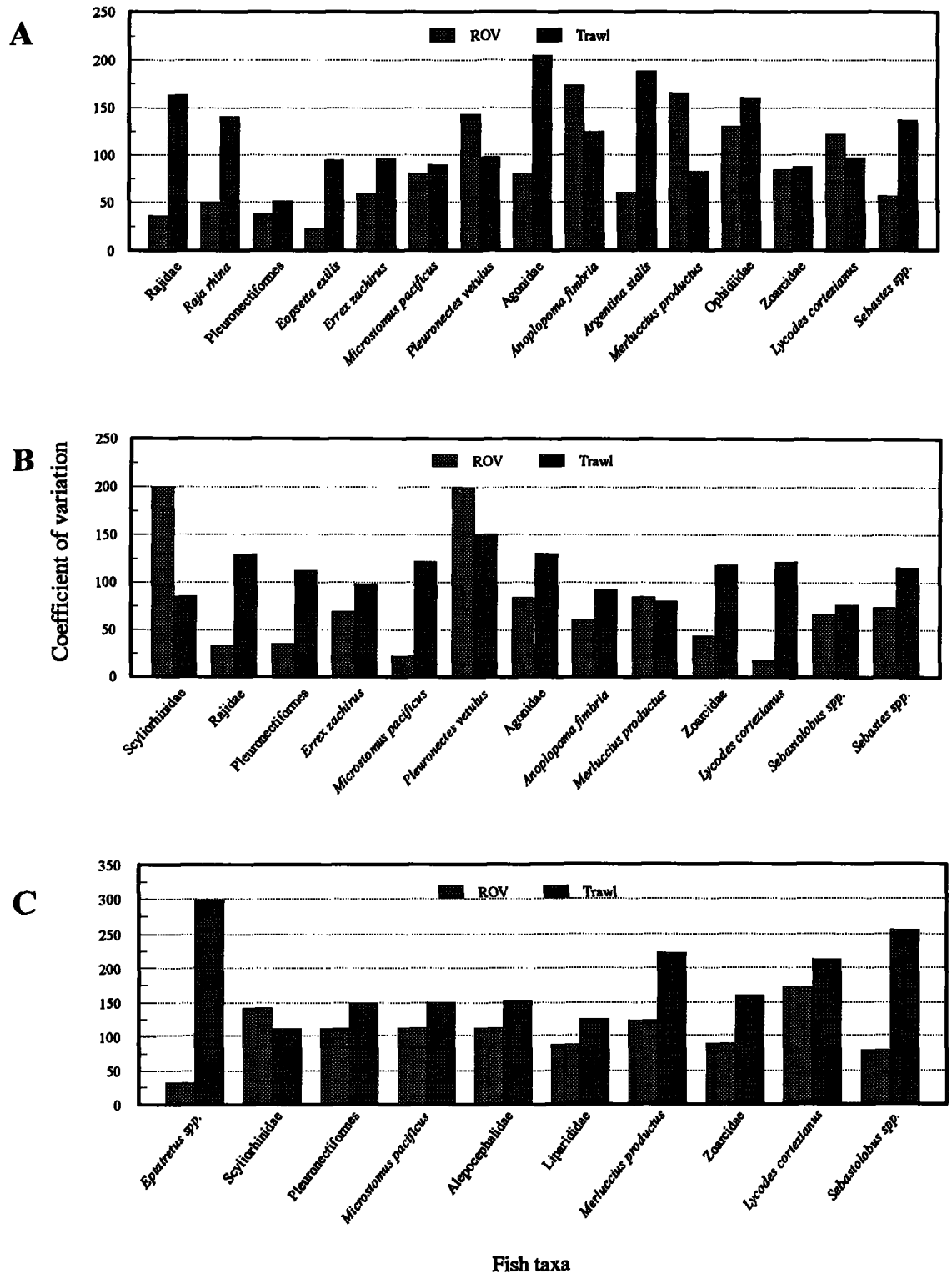

Figure 4

Coefficients of variation of the mean number of fish per hectare estimated from an ROV video strip-transect survey and a swept-area trawl survey from (**A**) the 200-m depth station (ROV, n=3 and trawl, n=8); (**B**) the 400-m depth station (ROV, n=4 and trawl, n=8); and (**C**) the 600-m depth station (ROV, n=3 and trawl, n=9).

avoided it. Pacific whiting had the strongest response (69%), appearing to be attracted to the ROV. Sablefish had the next strongest response (62%), but their numbers were low, averaging 3.75 individuals over all depths. Their behavior was variable: some animals swam away, some swam toward the ROV, and some ignored the ROV. Catsharks showed approximately equal numbers responding and not responding, and those that did respond consistently avoided the ROV.

Finally, the red octopus, *Octopus rubescens*, was the most abundant animal counted from the ROV. It was observed from the ROV only at the 200-m depth at numbers of 1,610 per hectare (SE=516.4) and was not captured in the trawls. The ROV red octopus abundance estimates were higher than any fish estimate from the trawls.

Discussion

Much of the difference between the ROV and trawl estimates was due to the different mechanical nature of the sampling gear and to the body shape and behavior of the fishes. The ROV intensively sampled a narrow area directly in front and extending up a short height off the bottom. The trawl sampled a much wider area, including a larger area off the bottom, but with what must have been a great deal of escapement. The result was that ROV abundance estimates were higher and had lower coefficients of variation for fishes either strongly associated with the bottom or with a body shape and size, or both, that would pass through the mesh (such as the red octopus). Conversely, animals with highly patchy distributions and off-bottom behavior (catsharks, rockfish at the 200-m depth) had higher abundance estimates from the larger volume trawl. Although both the ROV and trawl estimates were adjusted to the same surface area, there was no adjustment made to reflect the 7.7 times greater off-bottom height sampled by the trawl (Fig. 2). Probably neither method does a particularly good job of estimating off-bottom fishes that are patchily distributed. Visual estimates of fish abundance either from submersibles (Uzmann et al., 1977) or from divers (Kulbicki and Wantiez, 1990) are reported to be higher than those from otter trawl estimates for multispecies assessments, but the reverse was true in this study for rockfishes (see also Krieger, 1993).

The smaller sample sizes required to detect a 50% reduction of the ROV abundance estimates would improve the ability to detect trends in abundance such that a smaller increment of change would be detectable. The degree on improvement would vary with species. Reductions of the order of 1.3 to 19 times in required sample size are sufficient to increase the ability to detect true changes in population size. Much of the decrease in required sample size (and increase in statistical power) comes from the much higher ROV abundance estimates. If samples are drawn from two populations with similar levels of variation, a 50% decrease in abundance of the larger estimate is much larger and therefore easier to detect. Unfortunately, a great deal of variation due to patchiness in fish distribution remains.

For an environmental assessment, the ROV estimates provide a better overall picture of the community than do the trawl estimates. While the similarity in the presence and absence of species in the two methods was surprisingly high, the ROV abundance estimates generally tended to be higher and had lower coefficients of variation. Species that were usually in direct contact with the bottom had much higher ROV abundance estimates than did those captured in the trawl. Small, cylindrically shaped fishes (hagfish, poachers, and eelpouts) had particularly large differences between ROV and trawl abundance estimates, probably owing to escapement under the footrope or through the trawl webbing. The most obvious example of escapement or avoidance was that provided by the red octopus, which was more abundant in the ROV sampling than any fish, but which was not captured by the trawl.

For the commercially important species at these depths (Dover sole, thornyheads, and sablefish), the results were mixed. For Dover sole and thornyheads, ROV abundance estimates were higher and coefficients of variation were lower. For sablefish, abudance estimates were higher for the trawl sampling at 200-m and 600-m depths. Although rockfish at the 200-m depth are not commercially important, the trawl estimates for this taxon were higher, and this is likely to be true of commercially important rockfishes.

Stock assessment integrates patterns of removals and information on year-to-year variation in recruitment from catch-at-age data with mean levels of abundance and longer term trends from survey data (Deriso et al., 1985; Methot, 1990). Using simulations, Kimura (1989) showed that, if survey data are biased, the results can be a precise, but biased, inference regarding the population. The higher ROV abundance estimates mean that trawl estimates are biased too low and that there is actually a larger difference between years of low population size and threshold levels of overfishing set by these assessments. The risk of overfishing is actually lower than that which was assumed. A more dangerous situation arises when bottom trawl estimates are larger than the ROV estimates, as with rockfish (also see Krieger, 1993). Here the difference between years of

low population and threshold levels of overfishing is actually less than that which was realized, a difference that increases the risk of overfishing.

ROV's have the ability to identify the degree of species' attraction to or avoidance of the sampling gear. Three species showed a strong response to the ROV: Pacific whiting, sablefish, and catsharks. Pacific whiting was the only species that was attracted to the ROV (Table 3). These three species are usually observed off-bottom and in motion, rather than resting in contact with the bottom. Fishes that are commonly in motion should be in a better position to respond quickly to stimuli (motion, light, etc.) around them. Understanding and accounting for fish behavior could improve the accuracy of an estimate. For trawl gear, the level of attraction or avoidance is unknown. Anecdotal evidence for attraction (crowding of fish between doors suggested by Krieger [1993]) and for avoidance (net sounder readings of rockfish rising up out of the path of the net [Adams[3]]), have been reported, but there is no simple way of evaluating these phenomena for trawl gear.

While the presence of large seasonal or interannual variation in fish numbers could have introduced bias into the estimates, there is no reason to believe this occurred. None of the 20 most common species captured by the three trawl surveys, which covered almost the entire study period, exhibited a consistent seasonal or overall trend in fish abundance. Also, the consistency of trends in abundance derived from ROV's and trawls from all depths, even though they were sampled at different times, suggests that large varations in abundance were not an important source of bias. However, if this bias had occurred, it would have been a larger problem for the ROV estimates than for the trawl estimates. The ROV samples at depth were taken during one time period, with the exception of the 400-m depth, whereas the trawl samples were taken at all depths during three cruises over nearly the entire time period.

Both ROV and trawl surveys contain additional information that may be critical to the goals of an abundance study. ROV surveys provide much biological information, particularly on habitat and species association. In two instances, we observed feeding behavior. Trawl surveys deliver the fish on deck; for common types of biological studies, such as ageing or food habits, these specimens are critical. In addition, these specimens enable accurate species identification. Identifcation, however, is expected to become less of a problem as video technology improves.

[3] Adams, P. National Marine Fisheries Service, Tiburon Laboratory Southwest Fisheries Science Center, 3150 Paradise Dr., Tiburon, CA 94920. Personal commun., 1986.

Finally, there is the chronic problem of the low statistical power of tests of these abundance estimates owing to large, associated variances. Since increasing the sample size is often not practical, the only alternative is to stratify the sampling more effectively rather than simply on the basis of depth. Better stratification can come only from a greater understanding of the biological factors responsible for fish distributions. An adequate understanding would include the association of fish with microhabitat and the biological behavior of fishes that leads to patchiness. Surveys could then be stratified on the basis of areas where fish are occurring at background levels and in large patches. Trawl surveys have been unsuccessful in achieving such separation. Information gained from the ROV could lead to the biological understanding necessary to achieve more efficient stratification designs.

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Massachusetts Water Resources Authority

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FINAL ANALYSIS REPORT

FOR

MWRA HARBOR AND OUTFALL MONITORING PROJECT

Submitted to

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SUMMARY

Over eight hours of color video and 186 still photographs were collected along 9 km of seafloor near an outfall diffuser within Massachusetts Bay. Transects were divided into 50-m subsections along which benthopelagic megafauna were enumerated and bottom conditions digitized. The survey was conducted for reconnaissance of monitoring sites to be used in assessing potential anthropogenic effects from future wastewater discharge. Sites suitable for hard-substrate sampling were selected based upon proximity to the diffuser, continuity of megafaunal distributions, and four combinations of water depth and substrate relief height. The highest megafaunal similarities occurred between adjacent subsections which traversed seafloor areas of similar water depth and substrate height. Shallow high-relief sites were most common with five regions suitable for hard-substrate monitoring. These five regions covered over 3 km of seafloor at water depths shallower than 30 m and at distances ranging between 290 m and 1200 m from the diffuser. The three regions recommended for monitoring of shallow low-relief epifauna covered nearly 1.4 km of seafloor at distances ranging between 300 m and 1,400 m from the diffuser. Because of the geomorphology of the region, deep (>30 m) hard-substrate sites were less common, particularly for high-relief features (*viz.*, those extending beyond 1 m above the seafloor). The four regions characteristic of deep low-relief megafauna span a total distance of over 2 km and range between 64 m and 868 m from the diffuser. Four regions deemed suitable for sampling of deep high-relief epifauna covered only 334 m of seafloor and included one of the diffuser caps. Thus, distance from the diffuser-cap corridor ranged between 0 m and 217 m for deep high-relief sites.

1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

This report summarizes the results of a hard-substrate benthic reconnaissance survey (Imamura, 1994) conducted within Massachusetts Bay using a remotely operated vehicle (ROV). The survey is part of an ongoing effort to characterize the marine environment around the diffuser-cap corridor at the terminus of the outfall recently constructed for the Massachusetts Water Resources Authority (Figure 1). Wastewater discharge is expected to begin in May 1996 and studies conducted to date provide baseline pre-discharge data which will be used to assess future impacts of the outfall. The reconnaissance survey was intended to provide a "semi-quantitative" census of seafloor features and associated megafauna. This census was to be used to select future monitoring sites where fully-quantitative investigations could be conducted. The fully-quantitative field sampling would be designed such that statistical hypotheses concerning potential anthropogenic effects could be rigorously tested.

Six transects were traversed during the reconnaissance survey. The location of the six transects were selected to survey faunal distribution along the tops of drumlins and along depositional lows within 2 km of the diffuser-cap corridor. Figure 1 shows the location of the study area along with target transects. Data collected along the transects consists of continuous color video images and opportunistic still photographs of benthic epifauna. Extensive analysis of these images established a database that documents the distribution of bottom type and large benthopelagic organisms within 2 km of the diffuser-cap corridor (Coats and Campbell, 1994). Organisms of identifiable size ($\geq$5 cm) or color contrast were enumerated from an examination of over eight hours of color video images collected along the six transects. Post-survey navigational locations of the ROV are superimposed on target transects in Figure 2. Lateral excursions from target transects were minimal and generally less than 100 m. To quantify local variability in substrate and epifauna, transects were divided into subsections with a 50-m nominal length. Occasionally, subsections were prematurely shortened due to ROV entanglement in lobster-trap lines and subsequent surfacing. This results in the discontinuities between subsections shown in Figure 2. The length of the remaining subsections ranged from 30 to 84 m. In addition to biological enumeration, the character of the substrate was categorized along each subsection.

In this report, the resulting census and bottom-type data are used to select hard-substrate sites for future monitoring of potential effects from outfall discharge on the local epifaunal community. Presently, monitoring of the benthic biological community is conducted only at sedimentary sites surrounding the diffuser-cap corridor (*e.g.*, Coats *et al.*, 1995). Addition of hard-substrate monitoring sites will supplement existing soft-bottom monitoring of benthic fauna in several ways. First, existing sedimentary sites are mostly located to west of the diffuser because of the paucity of soft-substrate regions to the east suitable for grab sampling. Addition of hard-substrate monitoring locations to the east of the diffuser-cap corridor would provide a more radially-symmetric sampling design. However, given the comparatively weak residual circulation in the region, it is unlikely that the existing soft-substrate sampling locations would miss significant impacts due to preferential advection of the outfall discharge to the west.

Another enhancement offered by a hard-substrate sampling is an expanded depth range. Soft-bottom sampling sites tend to be located in topographic lows where accumulation of sediment is sufficient for grab sampling. Consequently, the depth range of nearfield soft-bottom sites does not reflect the actual range in local bathymetry. Because of the comparative lack of depth variability, the relationship between nearfield infaunal distribution and depth was found to be weak compared to that of far-field infaunal stations, which traverse a wider range in depths over broad areas in Massachusetts and Cape Cod Bays (Coats *et al.*, 1995). As will be shown in this report, many benthopelagic macrofaunal taxa within 2 km of the diffuser-cap corridor also exhibit a significant depth-related distribution. The addition of hard-substrate sampling sites atop nearfield moraines would allow assessment of potential anthropogenic effects on taxa endemic to water depths shallower than the depositional lows sampled by nearfield infaunal stations. In addition to depth differences, hard-substrate monitoring sites

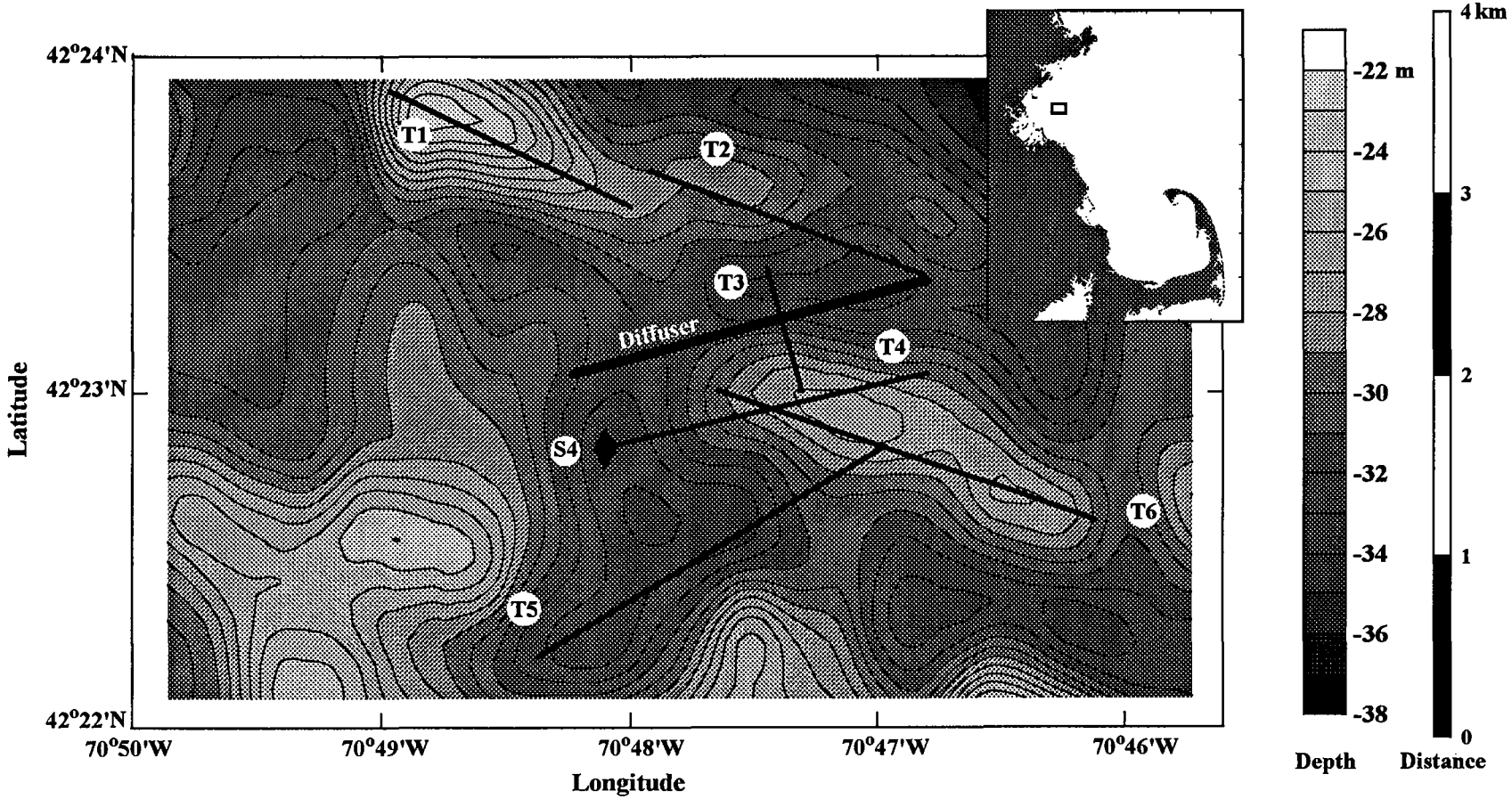

Figure 1. Location of target transects superimposed on topography determined by Bothner et al. (1992). Also shown is the location of the benthic infaunal Station S4. Inset shows the study-area location within Massachusetts Bay.

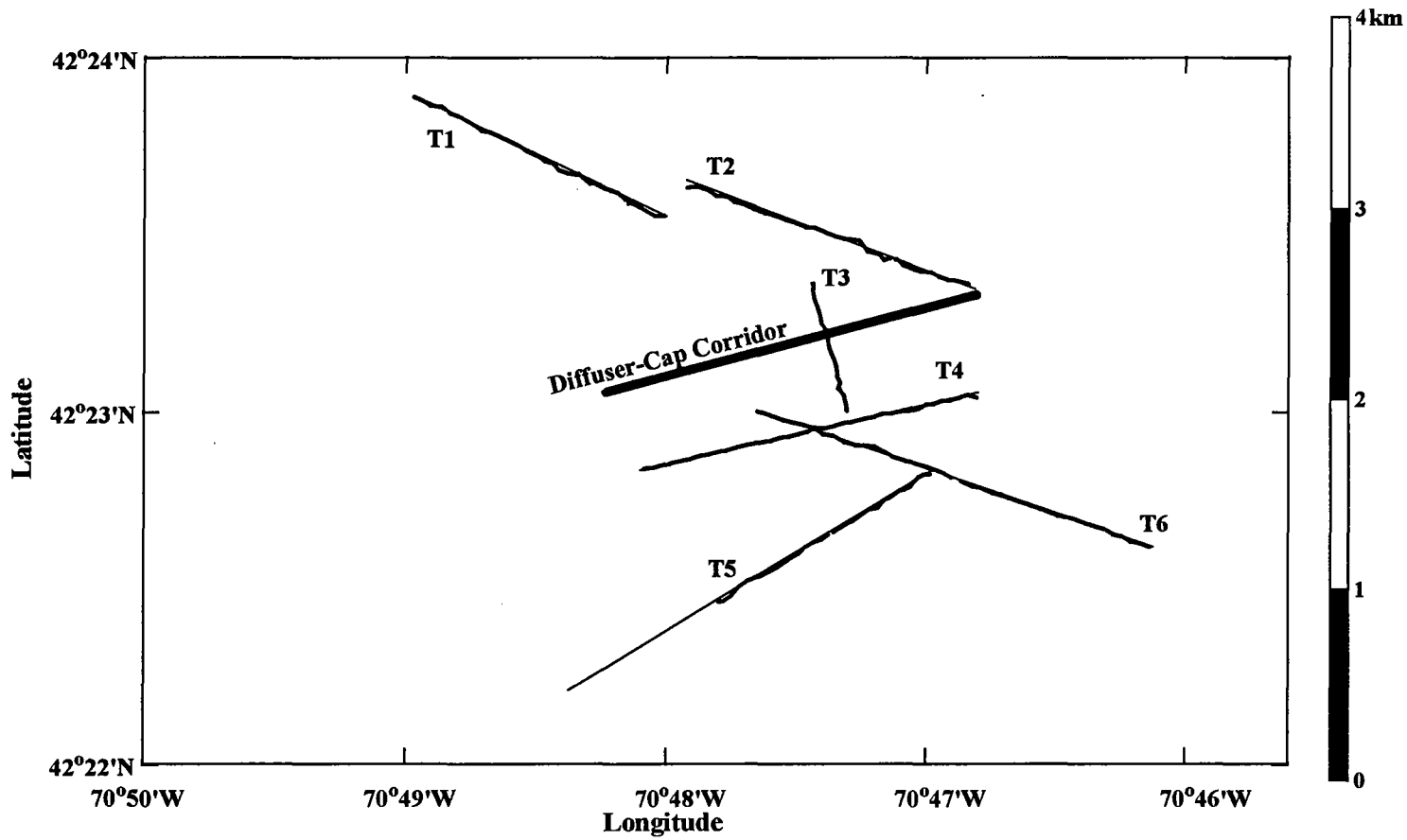

Figure 2. Post-survey location of transects. Heavy lines reflect the actual course of the ROV and light lines are target transects from Figure 1.

could increase anthropogenic detectability because of faunal differences between hard and soft-substrate communities were fully quantitative studies to be pursued. The hard-substrate epifauna observed in this survey include organisms, such as anemones, related to those found to be sensitive to increased particulate loads offshore California (Hyland *et al.*, 1994). In any regard, hard-substrate epifauna could react differently to sewage effluent exposure and their inclusion is likely to enhance the overall monitoring effort.

A second, ancillary objective of this report is identification of additional sedimentary sites near the diffuser corridor that could augment the benthic infaunal sampling array used in prior years (Blake *et al.*, 1993; Coats *et al.*,1995). For example, a new sedimentary site close to the diffuser, designated Station S4, was successfully sampled for benthic infauna and sediment chemistry with a grab sampler in 1994 (Campbell, 1994). Station S4 is located 450 m off the southwest end of the diffuser-cap corridor, near the end of Transect T4 (Figure 1). Because it is a new soft-bottom sampling location, the long-term stability of its sediments and their lateral extent is of interest for continued monitoring. Some discussion on the character of this and other depositional regions is included in Section 4.2.

Because the survey was only intended for reconnaissance purposes, the resulting database used herein, does not provide a fully-quantitative baseline characterization of hard-substrate communities suitable for detecting future effects of effluent discharge. This is due to a number of limitations in the database. First, there was no *a priori* attempt at replication. Also, video imagery was of limited resolution and the resulting enumeration undoubtedly underestimates the abundance of smaller benthopelagic species (Uzmann *et al.*, 1977). Finally, the image area was not precisely determined as part of the reconnaissance survey. The distance of the ROV from the bottom ranged between 1 and 3 m, and image size was generally consistent within the survey. While this was adequate for site reconnaissance, fully quantitative baseline characterization of hard-substrate biological communities requires more rigorous sampling protocols. For example, replicated still photographs of known latteral dimension and quality sufficient to fully identify megafaunal organisms would permit quantitative enumeration using techniques described by Foster *et al.* (1991). Knowledge of the photoquadrat size is crucial for precise quantification of areal abundance estimates. Thus, while the abundance database may not be acceptable for comparison with other studies, or as baseline data for detecting anthropogenic effects, it is suitable for contrasting the epifaunal community along the different sections of transects covered by the reconnaissance survey.

1.2 CRITERIA FOR SELECTING MONITORING LOCATIONS

Three criteria will be used for selecting candidate hard-substrate monitoring sites. First, the character of the hard substrate, specifically the lateral extent, density and size of rocks and boulders, will be compared among candidate sites. Quantitative sampling, for example using photoquadrat techniques, requires the presence of many suitable sampling locations for replication, namely, numerous rock surfaces in close proximity that have dimensions comparable to or exceeding the camera's field of view. A second criterion pertains to the biological community structure at the candidate sampling site. As will be shown in this report, the distribution of certain taxa is dictated by water depth and substrate size (*e.g.*, high-relief versus low relief). Lastly, the third criterion is proximity to the diffuser. Testing statistical hypotheses for anthropogenic effects will depend on a comparison of similar sites both close to the effluent discharge (treatment sites) and remote from effluent effects (control sites).

Most of the analyses reported here address the second criterion relating to the distribution of megafaunal organisms. Future studies conducted to detect change in the hard-substrate epifauna will require an analysis of variance on photoquadrat data with several treatment conditions (*e.g.*, deep versus shallow, nearfield versus farfield, high-relief versus low-relief). An adequate statistical sample for detection of anthropogenic change in deep benthic communities requires a large number of replicate photoquadrats, nominally 60 (Hyland *et al.*, 1994) to 80 (Hardin *et al.*, 1993), from sampling sites of similar character. In shallower areas, the higher faunal density may allow far fewer replicates, such as the 12 replicates used for rocky subtidal communities in Massachusetts

Bay (Witman and Sebens, 1993). Collection of an adequate number of replicates at depth requires a region with uniform physical and biological characteristics over a spatial extent that is large compared to the photoquadrat size (nominally ≤ 1 m). To this end, similarity analysis of community structure, described in Sections 3.0, serves to identify regions where the benthic biology is relatively uniform. Specifically, groups of adjacent subsections with highly similar community structure are specified for sites with four different physical characteristics: i) shallow high-relief, ii) shallow low-relief, iii) deep low-relief and iv) deep high-relief. Section 2.0 describes the methodology used to analyze the benthopelagic community structure. Finally, Section 4.0 recommends candidate sites on both hard and soft substrate, suitable for future monitoring efforts.

2.0 METHODS

2.1 FIELD SURVEY

The hard-substrate reconnaissance survey (S9404) was conducted on September 16 and 17, 1994 (Imamura, 1994). The M/V *Marlin* served as support-ship to a Phantom DS4 Remotely Operated Vehicle (ROV). Photosamples were collected using a high-resolution color video camera and a 35-mm still camera mounted on the ROV. Photosamples were gathered near the diffuser-cap corridor along six transects shown in Figure 1. Digital data pertaining to the ROV depth, heading and position as well as transect number and time were overlaid on video images. These data were digitized (Coats and Campbell, 1994) and form the basis of the analyses described in this report.

2.2 SAMPLE ANALYSIS

A variety of techniques have been developed to quantify macrofaunal species (generally fishes) using video images collected by ROV (*cf.*, Michalopoulos *et al.*, 1992). They are based on either counts per unit time or distance. This analysis uses strip transect techniques (*e.g.*, Auster *et al.*, 1991) based on distance covered. Species-time techniques are problematic because the ROV speed varied substantially over the reconnaissance survey. Also, precise ($\approx$ 1 m) navigation was available for distance computations and strip transect techniques produce spatially-based density estimates similar to those of infaunal monitoring studies.

Digitization and faunal enumeration of over 8 hours of color video and 186 still photographs were described in the data report for this survey (Coats and Campbell, 1994). Additionally, the character of the substrate was classified along each transect subsection as was the water depth and location. Substrate categories are listed in Table 1. Fauna was visually identified and enumerated from the video images along each transect subsection. Because of their inherently higher resolution, still photographs acted as visual voucher specimens and confirmed taxonomic identifications determined from video images. Two encrusting organisms, *Porifera* sp. A and a form of *Lithothamnium* spp., could not be counted individually and a percent cover was determined instead. The length of transect subsections varied for a number of reasons, including surfacing of the ROV due to entanglement or avoidance of lobster-trap lines. To compare the abundance of organisms in subsections of differing lengths, the number of organisms observed on the video was normalized by the length of the subsection. The resulting lineal densities (number of individuals m^{-1}) for the thirty-seven identified taxa were used in epifaunal analyses described below.

Table 1. Categories used to characterize the hard-substrate features encountered along transect subsections.

Size Range: Diameter of the largest hard-substrate features

Category	Size Range
Absent	Little or no hard-substrate larger than 1-in diameter
Cobbles	1 in ≤ diameter < 6 in
Rocks	6 in ≤ diameter < 3 ft
Boulders	3 ft ≤ diameter < 9 ft
Large Boulders	≤ 9 ft
Diffuser	Diffuser Cap (≤ 9 ft)

Distribution: Skewness of the frequency distribution of hard-substrate features

Category	Size Distribution
Uniform	All features are nearly the same size
Skewed	Majority of features are of the largest size
Broad	Sizes are uniformly distributed

Coverage: Amount of hard-substrate encountered along a transect subsection

Category	Coverage
Rare	0-25% hard-substrate cover
Scattered	26-50% hard-substrate cover
Dense	51-75% hard-substrate cover
Continuous	76-100% hard-substrate cover

Veneer: Type of material, if any, covering hard substrate features

Category	Veneer
Bare	Majority of rock was exposed
Detritus	Thin veneer of detritus covered most rock surfaces
Hydroid	Hydrozoan turf covering rock
Sediment	Thick sediment

Grain Size: Type of granular material surrounding hard substrate features

Category	Grain Size
Mud	Silt and Clay
Coarse	Sand and gravel

2.3 MEGAFAUNAL ANALYSES

Data resulting from fully-quantitative photoquadrat analyses are biological abundance measures similar to those determined for infaunal organisms as part of the outfall monitoring program (*e.g.*, Coats *et al.*, 1995). Specifically, areal density of epifaunal organisms is computed by normalizing the number of organisms within a specific taxa by the area of hard-substrate observed within each photoquadrat. In a fully quantitative analysis, the quadrat size can be precisely determined from computations of coverage area of the still photograph. Ideally, image area can be determined from the focal length of the camera lens, its angular field-of-view, the camera's distance from the organism, and the angle of inclination of the viewing axis (Wakefield and Genin, 1987). However, organism density estimates are sensitive to the variability in image area and, over a rough

bottom, the requisite positioning and stability of the camera platform is often not practical. In some studies (*e.g.*, Hecker, 1990), introduction of objects of known dimension (*e.g.*, metric scales or grids) into images has provided coverage information suitable for projecting life-size images during identification and enumeration of megafauna. The use of comparatively unstable ROVs as camera platforms has prompted a more direct method for determining scale information. It is now common to use parallel lasers that produce small light spots of known separation on a video image or still image (Tusting and Davis, 1992; Davis and Pilskaln, 1992). Video images collected using an ROV are subject to its changes in altitude, pitch, and roll which results in a variable field of view along transects.

The data provided by the hard-substrate reconnaissance survey differs from quantitative still photoquadrat data in some other significant ways. First, since still photographs were not intended for quantitative analysis, they were collected in an opportunistic rather than random manner. For true replication, photoquadrats should be collected randomly. Instead, since the reconnaissance photographs were primarily for identification of organisms rather than enumeration, particularly clear images of representative biological specimens were sought. Furthermore, the image coverage area and the substrate type and orientation were of a lesser concern than image quality.

The color video images used in this study to quantify biological distributions, differ from fully quantitative photoquadrat surveys in another way. The strip transect analysis technique results in lineal rather than areal density estimates of organism abundance. Consequently, abundance determined in this study cannot be directly compared with that of infaunal investigations (*e.g.*, Coats *et al.*, 1995 and Blake *et al.*, 1993). Although lineal density derived from video is only semi-quantitative compared to rigorously-conducted photoquadrat sampling, it has the advantage of rapidly characterizing large regions. This was the intent of this reconnaissance survey. Other limitations of the census database were due to variation in ROV speed over the seafloor, transit over a widely varying substrate within a single subsection, changes in video-camera angle relative to the seafloor and limited water clarity. Also, because of differences in the size and coloration of epifauna, the enumeration of certain taxa was more accurate and less sensitive to variations in the ROV sampling-platform than other taxa. Table 2 lists the thirty-seven identified taxa along with a qualitative assessment of the accuracy of the lineal density estimates. The epifaunal analyses described in this report, focus on those taxa whose enumeration was of moderate to high quality.

Table 2. Taxa identified in color video images listed by the relative accuracy of enumerations. Also shown is the taxon's rank by total abundance over all transects.

Taxon	Common Name	Accuracy	Rank
Boltenia ovifera	stalked tunicate	High	13
Agarum cribrosum	sea colander	High	8
Cancer spp.	crab	High	15
Homarus americanus	American lobster	High	14
Pleuronectes americanus	winter flounder	High	21
Placopecten magellanicus	deep sea scallop	High	21
Cerianthus borealis	northern cerianthid	High	23
Asterias spp.	sea star	High	10
Henricia sanguinolenta	blood sea star	High	9
Haliclona oculata	finger sponge	High	25
Metridium senile	frilled anemone	High	5
Ciona intestinalis	sea vase	Moderate	20
Crossaster papposus	spiny sunstar	Moderate	16
Strongylocentrotus droebachiensis	green sea urchin	Moderate	7

Taxon	Common Name	Accuracy	Rank
Halichondria panicea	crumb-of-bread sponge	Moderate	19
Raja laevis	barn-door skate	Moderate	31
Gadus morhua	Atlantic cod	Moderate	17
Tautogolabrus adspersus	cunner	Moderate	6
Urophycis spp.	hake	Moderate	28
Myoxocephalus spp.	sculpin	Moderate	22
Raja erinacea	little skate	Moderate	31
Halocynthia pyriformis	sea peach	Moderate	27
Melanogrammus aeglefinus	haddock	Moderate	31
Macrozoarces americanus	ocean pout	Moderate	30
Porifera sp. B.	leaf sponge	Moderate	26
Henricia sanguinolenta (juv)	juvenile blood sea star	Moderate	12
Modiolus modiolus	northern horse mussel	Low	3
Balanus spp.	barnacle	Low	4
Clupea harengus	Atlantic herring	Low	11
Rhodymenia palmata	dulse	Low	1
Rhodymenia sp A.	pinnate red algae	Low	2
Hemitripterus americanus	sea raven	Low	31
Pagurus spp.	hermit crab	Low	29
Porifera sp. A.	orange encrusting sponge	Low	a
Lithothamnium spp.	purple encrusting algae	Low	a
Porifera spp.	sponge	Low	18
Psolus fabricii	scarlet psolus	Low	30

[a] Encrusting taxa were quantified by percent cover and were not ranked with density estimates.

Three analyses were performed on the megafaunal data. The most basic was bathymetric profile plots combined with substrate size and taxon abundance along transects. Bivariate correlation was another common analysis technique used herein. Cluster analysis was the most important method used since it identified similar macrofaunal community structures among the large (193) number of transect subsections. The similarity between pairs of subsections was determined from numerical classification based on the unweighted pair-group method (Sneath and Sokal, 1973). Results were expressed in the form of dendrograms where sample pairs were ordered into groups of increasingly greater similarity as measured by resemblance between the abundance for individual species (Boesch, 1977).

The Bray-Curtis similarity coefficient (*B*) (Clifford and Stephenson, 1975; Swartz, 1978) was used to classify abundance data into groups of similar transect subsections. The similarity coefficient ranges between 0 and 1. For pairs of transect subsections that have identical numbers of individuals for each taxon, the coefficient is 1.00. The similarity coefficient is 0.00 when all taxa present in one sample are completely absent in the other sample and vice-versa. The Bray-Curtis coefficient was computed as follows

$$B_{jk} = \frac{2 \sum_{i=1}^{S} \min (N_{ij}, N_{ik})}{\sum_{i=1}^{S} (N_{ij} + N_{ik})}$$

where: B_{jk} = similarity coefficient between sample j and sample k
S = total number of species
N_{ij} = number of individuals for species i in sample j.

When computing B, the abundance (N) was logarithmically transformed.

3.0 RESULTS

3.1 MEGAFAUNAL COMMUNITY

The biological analyses described here were performed on epifaunal and pelagic taxa with large physical dimensions. For the purposes of this report, these taxa are designated megafauna. As described above, resolution limitation of the color video images prevents full identification and quantification of all epifaunal organisms. In practice, most organisms with diameters exceeding about 5 cm were successfully enumerated. Some smaller taxa, with coloration or shape easily distinguished from the surrounding substrate, were also identified. One example is the white juvenile sea star, whose high-contrast allowed rapid enumeration of most individuals even as small as 1 cm.

3.1.1 Comparison with Other Regional Studies

Many macrofaunal organisms observed in this study were also found in other video surveys in the region. In an area immediately to the south of Cape Cod near 40° 50'N, 70° 55'W, eight of the ten taxa observed by Auster *et al.* (1991) are listed in Table 2. Missing taxa included the shrimp *Crangon septemspinosa* and *Dichelopandalus leptocerus* which were deemed too small to enumerate without bias in the reconnaissance survey. Another video survey was performed by Battelle Ocean Sciences Center (1987) along transects covering a 95-km^2 area immediately west of the reconnaissance survey area. Twenty-three of the 37 taxa identified in video images from the 1994 reconnaissance survey were also identified from ROV video tapes in the 1987 survey.

The absence of eight of the 12 taxa in the earlier survey can be explained in terms of their low abundance in the 1994 survey. Seven of the missing taxa, *Cerianthus borealis* (northern cerianthid anemone), *Ciona intestinalis* (sea vase), *Crossaster papposus* (spiny sunstar), *Psolus fabricii* (scarlet psolus), *Raja laevis* (barn-door skate), *Gadus morhua* (Atlantic cod), and *Melanogrammus aeglefinus* (haddock) were only observed rarely in the recent survey and ranked in the lower 20 in abundance (Table 2). Also, although the ranking (11) of *Clupea harengus* (Atlantic herring) was relatively high, it resulted from a single encounter with large school. Differences in the remaining four taxa are more difficult to explain. Three of the remaining four taxa are macroalgae and include *Rhodymenia palmata* (dulse), *Rhodymenia* sp.A (pinnate red algae), and *Agarum cribrosum* (sea colander). Their absence may be due to differences in taxonomic identification since high abundances of *Fucus* spp. and *Laminaria* spp. were observed at some stations in the earlier survey. These taxa are typically associated with littoral and subtidal habitats much shallower than those of the surveys (Taylor, 1967). Also, one species of Laminaria, *L. agardhii* (southern kelp) is very similar in appearance to *A. cribrosum* (sea colander). The remaining missing species was *Strongylocentrotus droebachiensis* (green sea urchin). Although it was not described in the video transects of the earlier survey, it was collected by diver and by the ROV manipulator arm at some stations.

3.1.2 Relationship Among Taxa

A total of 26 of the 37 taxa was included in the numerical classification. Excluded were eight taxa, *Macrozoarces americanus* (ocean pout), *Pagurus* spp. (hermit crab), *P. fabricii* (scarlet psolus), *Hemitripterus americanus* (sea raven), *C. harengus* (Atlantic herring), *Raja erinacea* (little skate), *M. aeglefinus* (haddock), and *R. laevis* (barn-door skate), whose abundance was probably under sampled since they were only observed in less than four of the 193 transect subsections. Also excluded were the two encrusting organisms, *Porifera* sp. A (orange encrusting sponge) and *Lithothamnium* spp. (purple encrusting algae), which were quantified by percent cover rather than lineal density. Finally, unidentified sponges were also excluded to avoid confusion with identifiable species of sponge.

Two major groups, designated Group A and Group B, were identified by (R mode) numerical classification among taxa (Figure 3). Using a Bray-Curtis similarity index of 0.2 as a decision rule, the dendrogram separates all but four taxa into these two groups. Group A is the largest group and contains 17 of the 26 taxa present. Group B is three times smaller and contains only five taxa. The four taxa unaffiliated with the two cluster groups were *Urophycis* spp. (hake), *Haliclona oculata* (finger sponge), *Porifera* sp. B. (leaf sponge), and *Halocynthia pyriformis* (sea peach). All had comparatively low abundances as indicated by rankings exceeding 24 (Table 2). The two sponge taxa showed some affinity for one another at a similarity of 0.17. For reasons to be discussed in Section 4.2, *Urophycis* spp. (hake) was found exclusively along five transect subsections that were within large areas of thick sediment. This effectively isolated them from most of the other taxa which were distributed in areas containing hard substrate.

The high affinity among some taxa in Group A, described by relatively high (>0.75) similarity indices, can also be explained by anecdotal observations. Not surprisingly, the highest Bray-Curtis similarity index was computed between the two red algae, *R. palmata* (dulse) and *Rhodymenia* sp. A. (pinnate red algae). These taxa were consistently observed together on hard-substrate, and with great abundance at the shallow depth (<30 m). The algae *A. cribrosum* (sea colander) is also closely associated (*B*=0.56) with these taxa. A less intuitive affinity occurred between the sessile anthozoan *Metridium senile* (frilled anemone) and free-swimming fish *Tautogolabrus adspersus* (cunner) at a similarity of 0.77. Both species exhibited substantially higher abundances near large boulders. This unique spatial distribution accounts for a high similarity index between these apparently unrelated organisms.

Another high similarity worthy of note, occurred between taxa within the *Asterias* (sea star) genus and *Henricia sanguinolenta* juv (juvenile blood sea star). Normally, one would expect the highest similarity between the adult and juvenile forms of *H. sanguinolenta*. However, the juvenile form of sea star observed in the video images was small, close to the resolution capabilities for enumeration. Although marginal, it was postulated that these small sea stars were *H. sanguinolenta*. Assuming that juvenile and adult sea stars of these two species have similar habitat preferences, numerical classification suggests that most of these organisms were in fact, members of the genus *Asterias* rather than Henricia.

3.2 MEGAFAUNAL AND TEXTURAL DISTRIBUTIONS

This section examines various physical factors that determine the distribution of megafauna in the hard-substrate region with 2 km of the diffuser cap corridor. A similar study of deep hard-substrate communities offshore California (Hardin *et al.*, 1994) has shown that water depth and habitat relief (vertical dimension of the hard-substrate) are primary influences on epifaunal distribution. Other studies (Hecker, 1990; Rowe and Menzies, 1969; Haedrich *et al.*, 1975) have established a clear relationship between species composition and depth along the U.S. Atlantic Coast. The intent here is to establish ranges in the physical factors across which the megafaunal community structure is comparatively uniform. Transect subsections representative of these physical factors will then be selected to serve as candidate sites for a future fully-quantitative hard-bottom studies. With a fully-quantitative investigation, possible impacts from effluent discharge can be tested with a multiple analysis of variance model that accounts for confounding influences from natural variability in the physical environment.

3.2.1 Water Depth

The discussion now returns to the two major groups of taxa defined by the numerical classification of Figure 3. Initial speculation based on anecdotal observations suggests that groups were separated by substrate type. Three of the five taxa within the smaller of these two groups (Group B), namely *C. borealis* (northern cerianthid anemone), *Pleuronectes americanus* (winter flounder), and *Placopecten magellanicus* (deep sea scallop), were

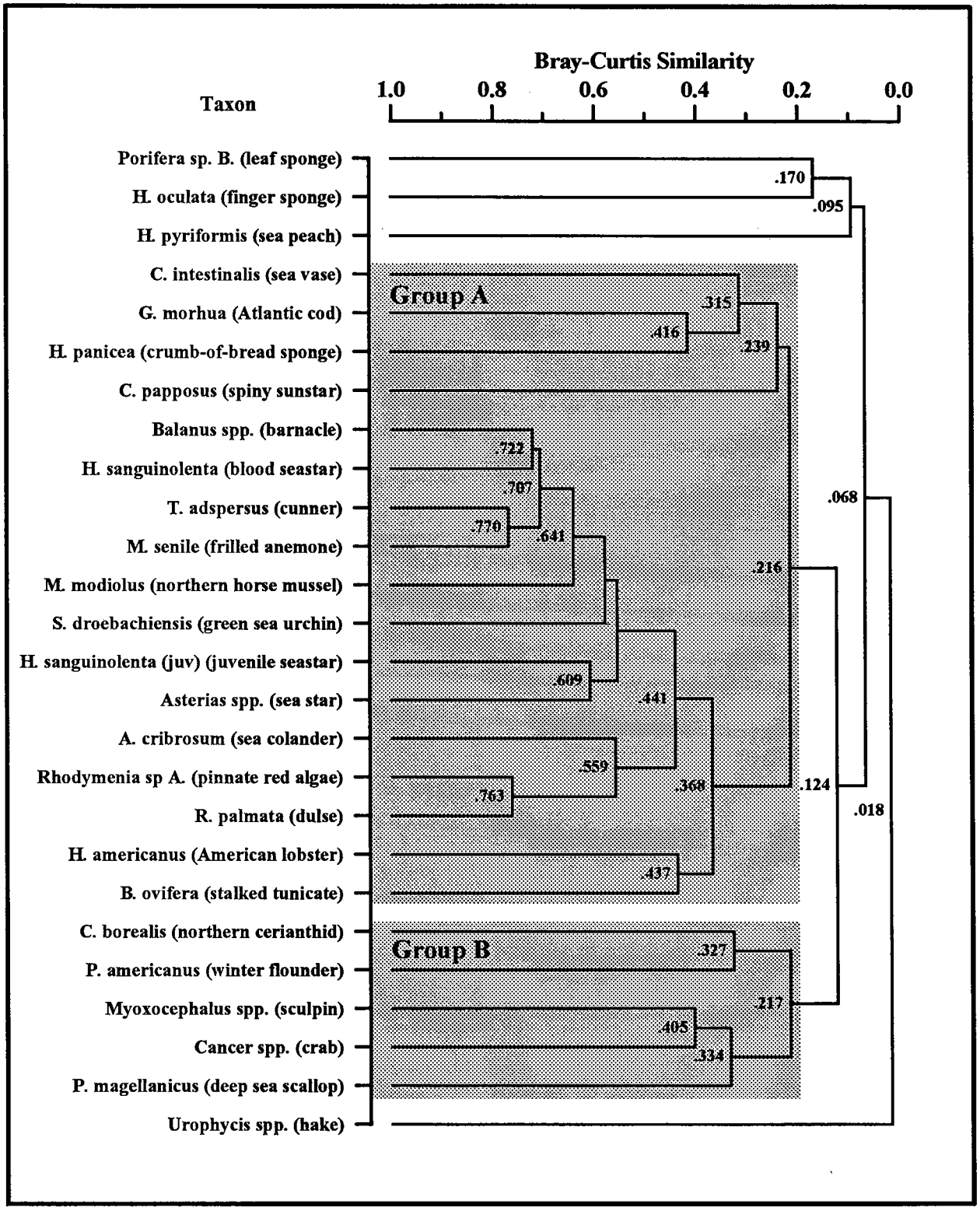

Figure 3. Dendrogram resulting from clustering (group average sorting) of Bray-Curtis similarity among the 26 taxa that were present in more than three transect subsections.

largely observed on sedimentary deposits rather than hard substrate. The 17 taxa in Group A were almost always associated with hard-substrate, although the highly motile organisms, *T. adspersus* (cunner), *G. morhua* (Atlantic cod), and *Homarus americanus* (American lobster), often ranged over sediment areas adjacent to hard-substrate features. From the foregoing discussion, substrate type appears to be an important influence on the distribution of taxa.

Anecdotal observations of a taxon's affinity for substrate type aside, a more quantitative analysis reveals that water depth and other related physical factors also serve to distinguish the two major cluster groups of Figure 3. Table 3 shows that the abundance of all five taxa in Group B was positively correlated with depth. Furthermore, their increased abundance at greater depth was statistically-significant at the 95% confidence level. In contrast, all but one of the 17 taxa in Group A were negatively correlated with water depth and eleven of these were statistically significant. *Asterias* spp. (sea star) was the sole positively-correlated taxon in Group A and its correlation was only marginally significant at the 95% confidence level.

Given that water depth was an important factor for megafaunal distribution, a single depth near 30 m was selected to partition "shallow" and "deep" regimes. Ideally, the transition depth would cleanly partition the abundance of all taxa by cluster group in Figure 3. In reality, each taxon differed in its distribution with depth and these differences cannot be determined from correlation coefficients alone. The Pearson correlations shown in Table 3 are predicated on a log-linear relationship between abundance and depth. While the abundance of some taxa varied monotonically with depth, others exhibited abrupt changes in abundance with depth. For example, the abundance of algae, shown in the bottom frame of Figure 4, declined abruptly below 28 m, and below 30 m, it was virtually absent. This is not surprising because macroalgae physiology requires sunlight for photosynthesis. Based on this information, the depth of the euphotic zone lies close to 30 m near the diffuser cap corridor.

In contrast to the depth distribution of macroalgae, tunicate abundance exhibited a nonlinear distribution as shown in the center frame of Figure 4. Although all had negative (linear) correlation coefficients, the abundance of *Boltenia ovifera* (stalked tunicate) reached a maximum near 28 m whereas the abundance of *C. intestinalis* (sea vase) was constant at depths less than 32 m. Other organisms in Group A of Figure 3, exhibited abundances that monotonically declined over the entire depth range as shown in the upper frame of Figure 4. A similar monotonic increase in abundance was evident in most of the positively-correlated taxa (Figure 5). Except for *Urophycis* spp. (hake), these taxa constitute Group B in Figure 3. Observations of *Urophycis* spp. were limited to depths below 32 m where large subsections containing deep sediments were found.

3.2.2 Relief Height

The vertical relief of hard-substrate features is another potential influence for epifaunal distribution. Unfortunately, the geomorphology of the study area made it difficult to separate the influence of water depth from relief height. This was because high-relief features (boulders) tended to be restricted to shallower depths. The Pearson correlation coefficient computed between water depth and substrate size was -0.49 over all transect subsections. The large negative correlation indicates a strong linear relationship between increasing water depth and decreasing substrate size. This relationship is not an artifact of the selected study area, but is instead, related to regional geology. The regional seafloor physiography consists of a series of elliptical drumlins with major axes oriented along 290°N (Figure 1). Two drumlins immediately adjacent to the diffuser-cap corridor were surveyed in this study. With a vertical relief of 10 m, they extend for 2 km along their major axis. An analysis of sonographs from the region by Knebel (1993) reveals erosional environments on the top of drumlins with deposition or reworking of fine-grained sediment at depth. Large boulders, some with diameters exceeding 3 m, were deposited along with other glacial till as part of the moraines. These boulder trains or erratics can be traced as strong acoustic reflectors in sub-bottom profiles as they extend under the sediments that fill

Table 3 . Pearson correlation coefficients between logarithmically-transformed taxon abundance and water depth. Shaded coefficients are not statistically significant at the 95% confidence level.

Taxon	Common Name	Depth Correlation
Cerianthus borealis	northern cerianthid	0.32
Myoxocephalus spp.	sculpin	0.28
Cancer spp.	crab	0.28
Placopecten magellanicus	deep sea scallop	0.28
Pleuronectes americanus	winter flounder	0.24
Urophycis spp.	hake	0.22
Pagurus spp.	hermit crab	0.18
Asterias spp.	sea star	0.16
Raja erinacea	little skate	0.11
Raja laevis	barn-door skate	0.11
Macrozoarces americanus	ocean pout	0.10
Porifera spp.	sponge	0.06
Hemitripterus americanus	sea raven	0.05
Melanogrammus aeglefinus	haddock	0.04
Clupea harengus	Atlantic herring	0.00
Crossaster papposus	spiny sunstar	-0.01
Psolus fabricii	scarlet psolus	-0.02
Haliclona oculata	finger sponge	-0.02
Porifera sp. B.	leaf sponge	-0.03
Henricia sanguinolenta (juv)	blood sea star juvenile	-0.05
Halichondria panicea	crumb-of-bread sponge	-0.06
Henricia sanguinolenta	blood sea star	-0.06
Gadus morhua	Atlantic cod	-0.11
Homarus americanus	American lobster	-0.11
Halocynthia pyriformis	sea peach	-0.14
Ciona intestinalis	sea vase	-0.17
Metridium senile	frilled anemone	-0.19
Boltenia ovifera	stalked tunicate	-0.21
Agarum cribrosum	sea colander	-0.36
Balanus spp.	barnacle	-0.37
Rhodymenia sp A.	pinnate red algae	-0.38
Modiolus modiolus	northern horse mussel	-0.51
Rhodymenia palmata	dulse	-0.53
Tautogolabrus adspersus	cunner	-0.56
Strongylocentrotus droebachiensis	green sea urchin	-0.70

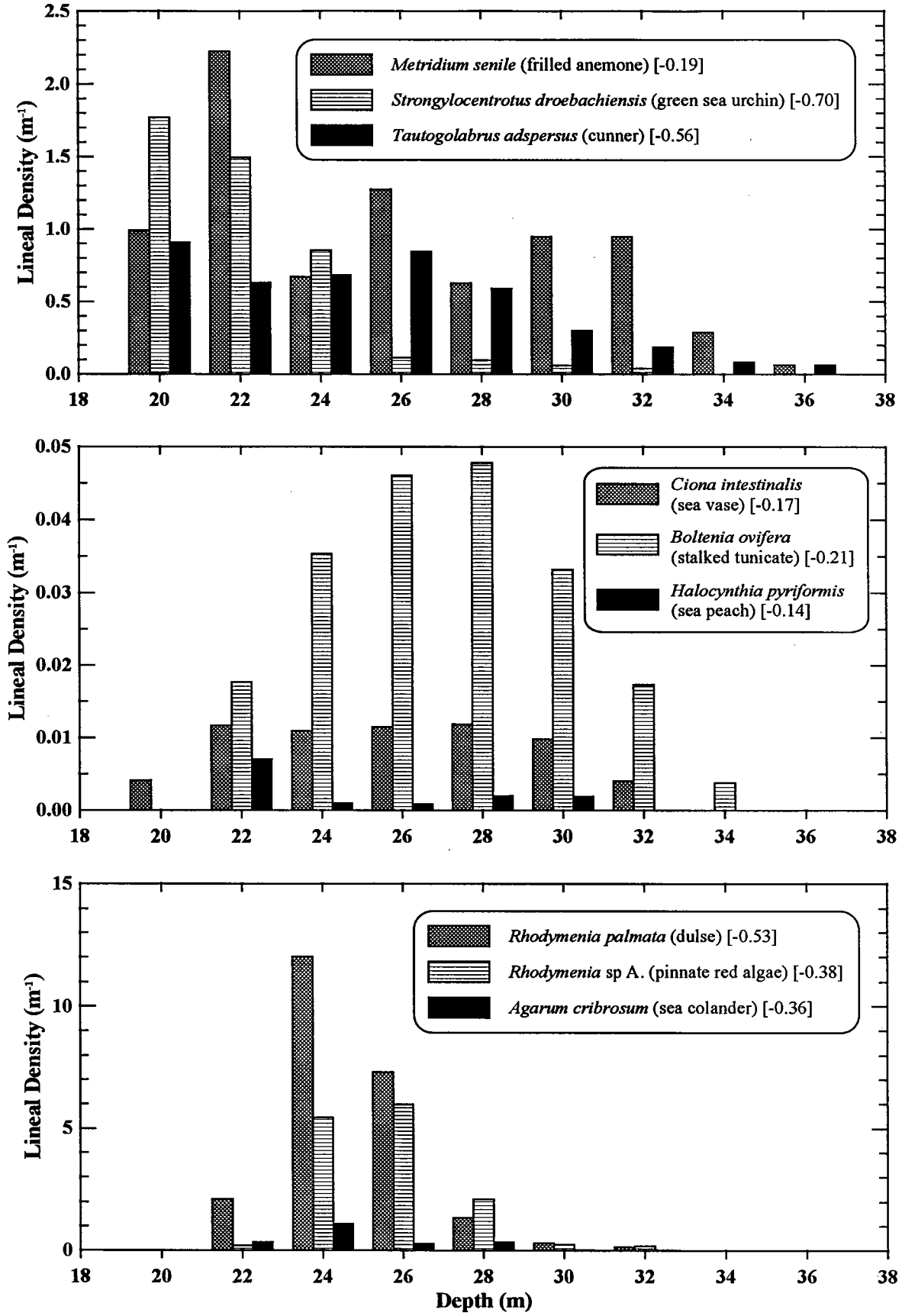

Figure 4. Depth distribution of selected taxa having a negative correlation with water depth. Correlation coefficients from Table 3 are shown in brackets.

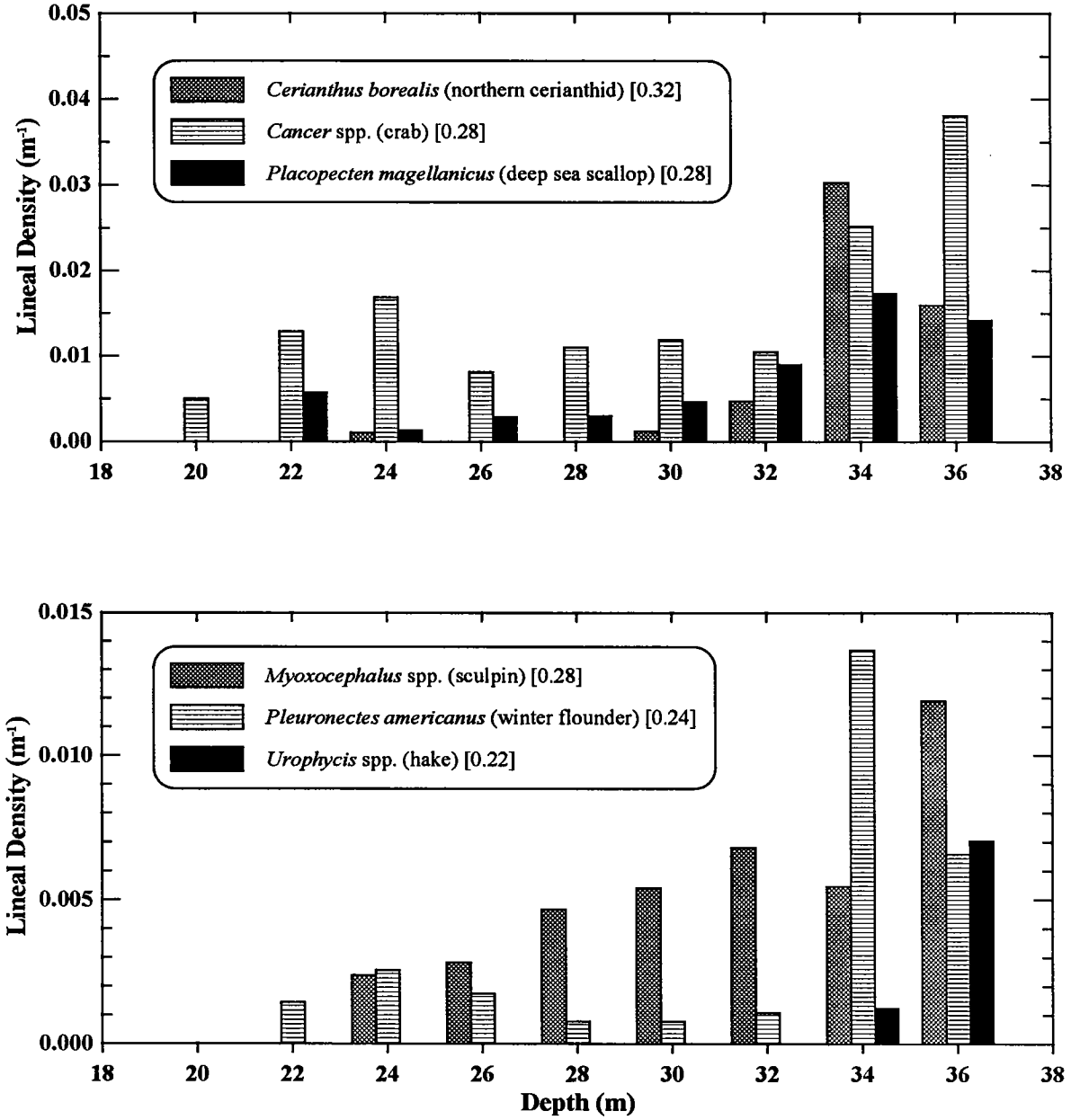

Figure 5. Depth distribution of selected taxa having a positive correlation with water depth. Correlation coefficients from Table 3 are shown in brackets.

adjacent depressions. Thus, large hard-substrate features are not absent at depth, but are buried and have no surficial expression on the seafloor.

For the purposes of this report, an important issue is whether relief height influences megafaunal distribution and, if so, what is a suitable size category to separate low-relief from high-relief. Because of the high correlation between depth and relief, little new information was gained from correlations computed between taxonomic abundance and substrate size. The bivariate correlations between relief height and abundance, shown in Table 4, mirror the depth/abundance correlations shown in Table 3. The principal exception was the sea star of genus *Asterias*. This could explain its anomalous inclusion in Group A of primarily shallow taxa in Figure 3. During enumeration of color video images, it was clear that the largest boulders were unique biological habitats. Often they were covered with a high density of *M. senile* (frilled anemone). The following discussion seeks to determine whether this species or other taxa were included in the cluster groups of Figure 3, because of relief height rather than depth.

Stacked plots of depth, substrate size, and abundance for selected taxa are presented in Figures 6 through 11 for Transects 1 through 6, respectively. The depth profiles in the bottom frames of the figures show that five of the transects traversed both deep and shallow regions. The exception is Transect T1 (Figure 6) which traversed the comparatively shallow area atop the drumlin immediately north of the diffuser-cap corridor (Figure 1). Comparison substrate size, shown in the frame immediately above depth in Figures 6 through 11 and in depth profiles (bottom frame), corroborates their negative correlation. When water depth was shallow (<30 m), such as in Figure 6, the substrate tended to consist of rock, boulders, or even large boulders (unlabeled tick mark above "boulders") with little cobble or deep sediments (tick mark labeled "none"). Transect T5 (Figure 10) provides another good example of this covariance where the shallow portion of the transect (Subsections S1 through S15) was the only region where substrate size exceeded that of cobbles.

Note that some transect subsections were much shorter than others, chiefly, for example, along Transect T1 (Figure 6, Subsections S6, S11, and S14) and Transect T6 (Figure 11, Subsections S10, S14, and S19). These short subsections contained isolated large boulders with a dimension exceeding 3 m (see size categories in Table 1). These very high relief substrates provided a habitat that was different from surrounding substrates, even boulders and large rocks. Shortening the 50-m nominal subsection length to include only these large boulders enabled computation of more accurate abundance estimates.

The extent to which the habitat differed on these and other hard-substrate features can be derived from the abundance of six selected taxa plotted in the upper frames of Figures 6 through 11. The *Asterias* spp. (sea star) taxon was selected because of its anomalous positive correlation with both depth and substrate relief. The taxa *P. magellanicus* (deep sea scallop) and *C. borealis* (northern cerianthid anemone) were representative of deep low-relief features as reflected in statistically-significant correlations shown in Tables 3 and 4. In contrast, the three remaining taxa typified shallow high-relief substrates. Of these three taxa, the distribution of *M. senile* (frilled anemone) abundance was particularly useful for distinguishing the influence of water depth from substrate relief. The only subsections where the lineal density of these organisms exceeded 10 m^{-1}, were those with large boulders. This supports anecdotal observations made during enumeration from color video concerning the tendency for this species to populate very high-relief substrates. However, some large boulders did not support an elevated abundance of this species. Along Transect T4 (Figure 9), the ROV encountered a large boulder at Subsection S13 that lacked a significant cover of *M. senile* (frilled anemone). This large boulder was the only one that also had a high (>1 m^{-1}) abundance of *A. cribrosum* (sea colander) suggesting some competitive relationship between macroalgae and *Metridium* spp. Nevertheless, the uniqueness of the large boulder as a high-relief habitat is undeniable and these features are emphasized in recommended future sampling sites of Section 4.1.

Table 4. Pearson correlation coefficients between logarithmically-transformed taxon abundance and substrate size. Shaded coefficients are not statistically significant at the 95% confidence level.

Taxon	Common Name	Size Correlation
Tautogolabrus adspersus	cunner	0.55
Metridium senile	frilled anemone	0.51
Rhodymenia palmata	dulse	0.44
Gadus morhua	Atlantic cod	0.42
Strongylocentrotus droebachiensis	green sea urchin	0.36
Boltenia ovifera	stalked tunicate	0.34
Agarum cribrosum	sea colander	0.31
Ciona intestinalis	sea vase	0.30
Rhodymenia sp A.	pinnate red algae	0.27
Henricia sanguinolenta	blood sea star	0.21
Asterias spp.	sea star	0.15
Halocynthia pyriformis	sea peach	0.14
Porifera sp. B.	leaf sponge	0.14
Halichondria panicea	crumb-of-bread sponge	0.12
Henricia sanguinolenta (juv)	blood sea star juvenile	0.09
Modiolus modiolus	northern horse mussel	0.09
Balanus spp.	barnacle	0.08
Hemitripterus americanus	sea raven	0.00
Clupea harengus	Atlantic herring	0.00
Crossaster papposus	spiny sunstar	-0.01
Psolus fabricii	scarlet psolus	-0.05
Haliclona oculata	finger sponge	-0.06
Homarus americanus	American lobster	-0.06
Porifera spp.	sponge	-0.08
Raja laevis	barn-door skate	-0.08
Melanogrammus aeglefinus	haddock	-0.08
Macrozoarces americanus	ocean pout	-0.09
Raja erinacea	little skate	-0.10
Pagurus spp.	hermit crab	-0.11
Urophycis spp.	hake	-0.16
Cerianthus borealis	northern cerianthid	-0.20
Myoxocephalus spp.	sculpin	-0.21
Cancer spp.	crab	-0.23
Pleuronectes americanus	winter flounder	-0.24
Placopecten magellanicus	deep sea scallop	-0.26

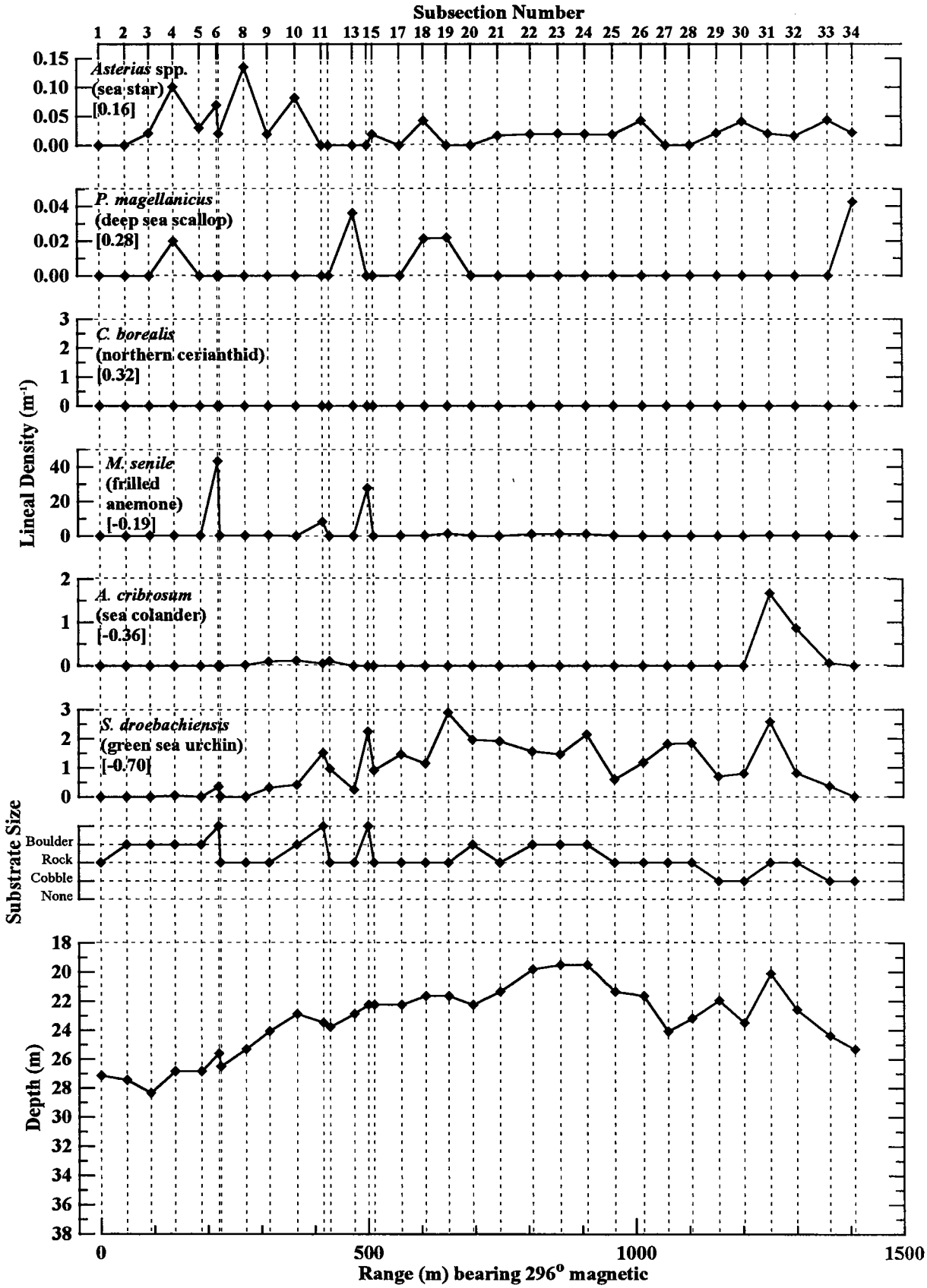

Figure 6. Variation in depth, substrate size and the abundance of six selected taxa along Transect T1.

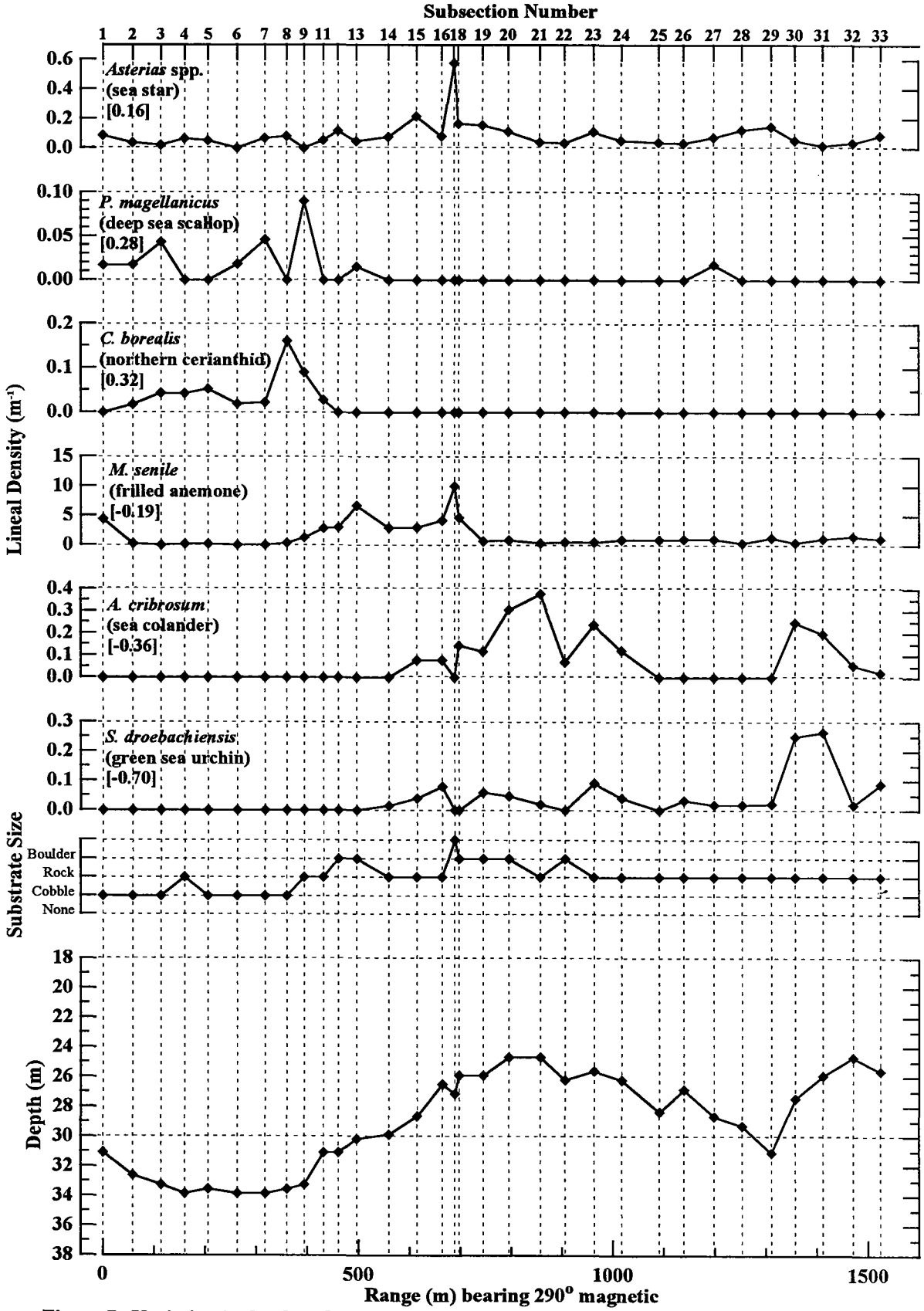

Figure 7. Variation in depth, substrate size and the abundance of six selected taxa along Transect T2.

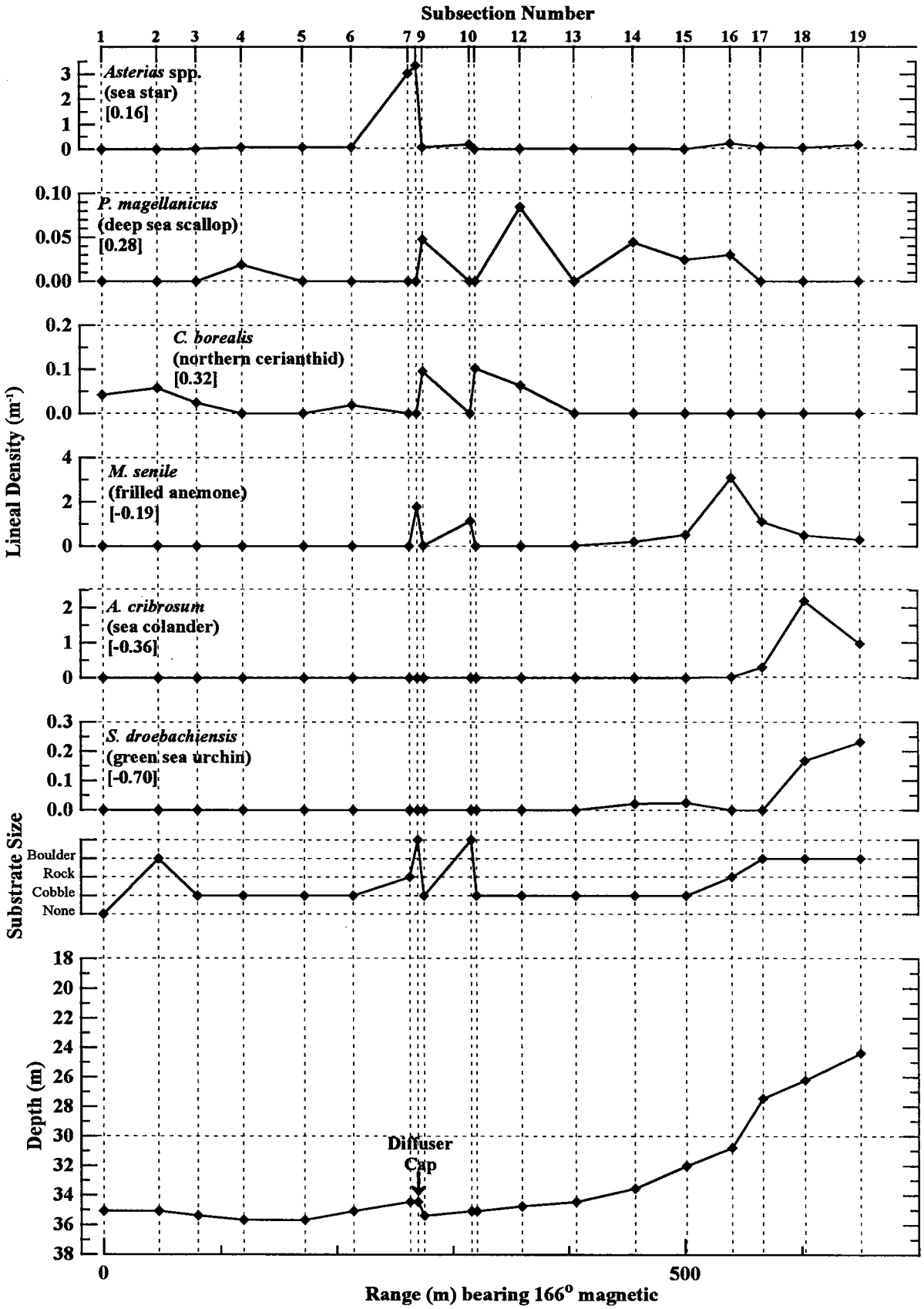

Figure 8. Variation in depth, substrate size and the abundance of six selected taxa along Transect T3.

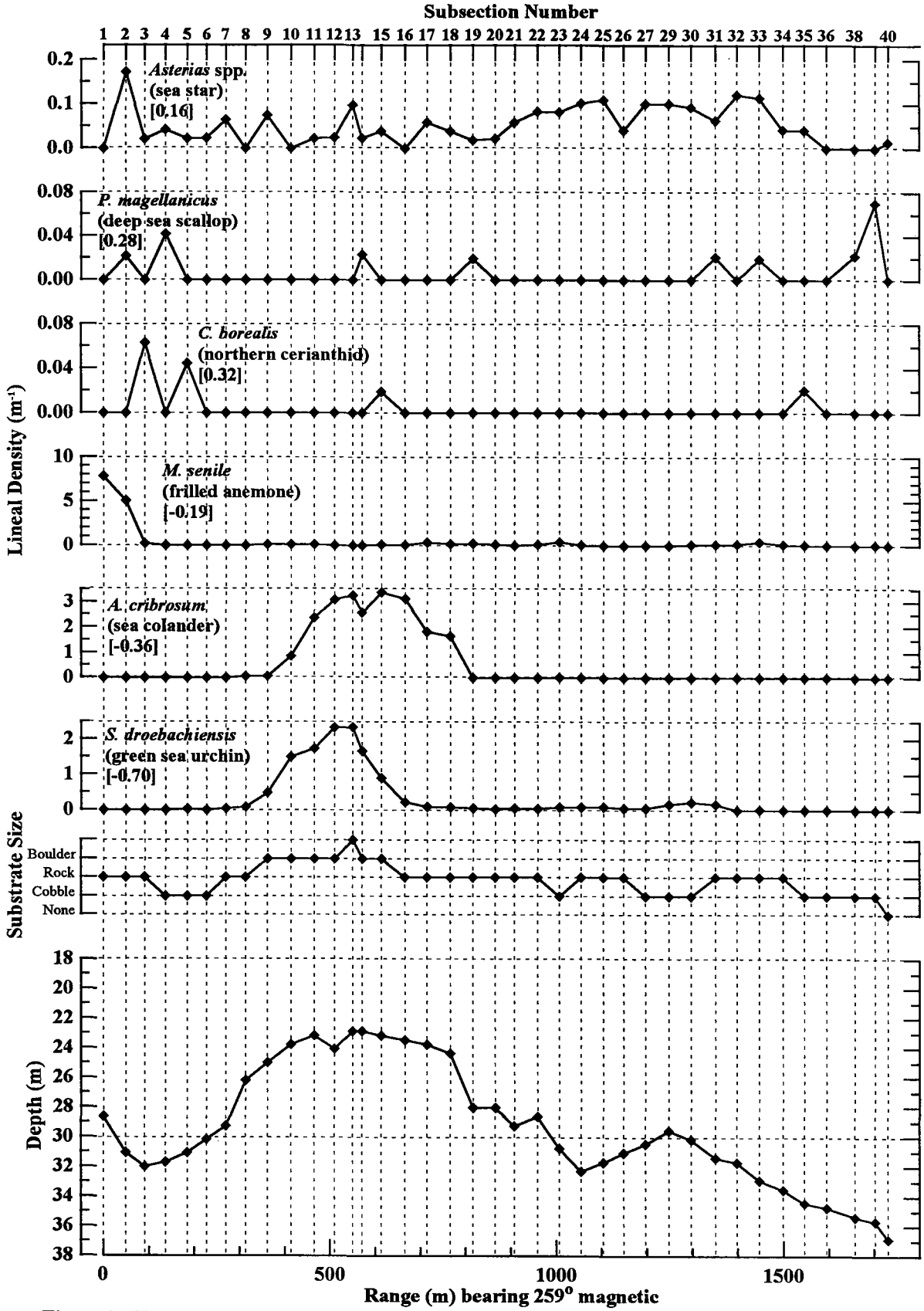

Figure 9. Variation in depth, substrate size and the abundance of six selected taxa along Transect T4.

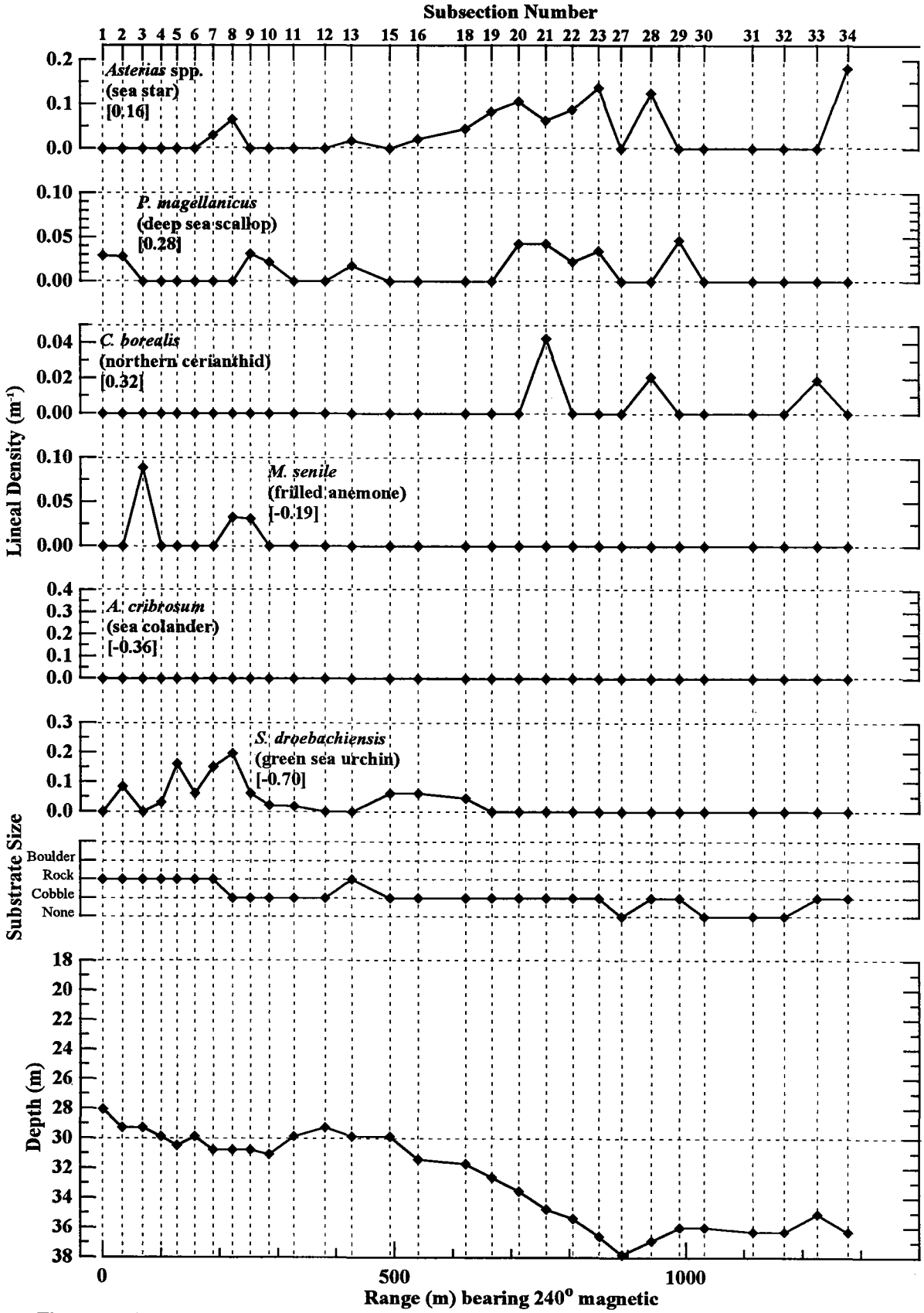

Figure 10. Variation in depth, substrate size and the abundance of six selected taxa along Transect T5.

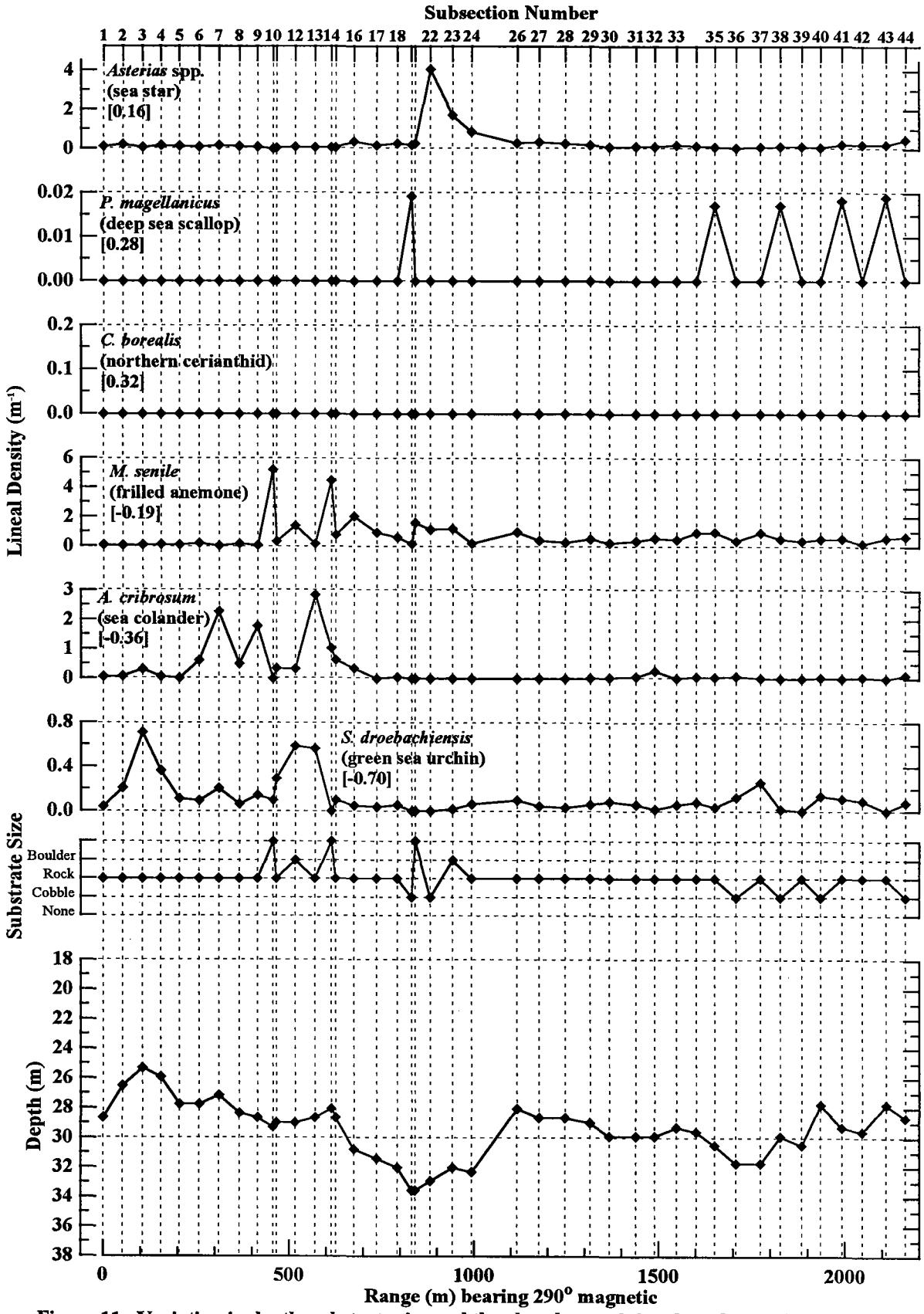

Figure 11. Variation in depth, substrate size and the abundance of six selected taxa along Transect T6.

The two taxa associated with deep water differed in their respective distributions. This lends further insight into relief height as a controlling factor. Anecdotal observations indicated that *C. borealis* (northern cerianthid anemone) was located within broad patches of sediment. These patches were often contained within cobbled subsections at depth. In contrast, *P. magellanicus* (deep sea scallop) was scattered among hard-substrate features and not always associated with deep sedimentary deposits. These observations are supported by Figures 6 through 11. *C. borealis* (northern cerianthid anemone) was almost absent at depths shallower than 30 m, and because of this, it achieved the highest positive depth correlation of any taxon (Table 3 and Figure 5). Elevated abundances of *P. magellanicus* (deep sea scallop) were, on the other hand, occasionally associated with shallower substrates of low relief (cobbles and rocks, *cf.* Figure 6). As a consequence, it exhibited the largest negative correlation with substrate size of any taxon (Table 4). Obviously, hard-substrate sites monitored in the future would exclude *C. borealis* (northern cerianthid anemone) in favor of *P. magellanicus* (deep sea scallop). However, both taxa were rare and any future monitoring program would probably undersample these species. Thus, exclusion of deep-sediment habitats and by association, *C. borealis* (northern cerianthid anemone), would not be detrimental to monitoring goals.

The distribution of *S. droebachiensis* (green sea urchin) closely tracks the depth profiles in Figures 6 through 11. This close correspondence explains why it had the largest negative correlation with depth, by far (Table 4). Its relationship to relief height was only weakly positive (Table 4). The depth dependence of the herbivore *S. droebachiensis* may be a consequence of the distribution of its food supply as reflected by the negative depth correlations in some algal taxa. The distribution of sea stars of the genus *Asterias* differed from that of other taxa because they were positively correlated with both water depth and substrate size. Because of the regional geomorphology described above, there were very few instances of deep high-relief features which makes the anomalous correlations even more curious. However, the anomalous correlations are the result of high *Asterias* spp. abundance (>3 m^{-1}) near the diffuser cap surveyed on Subsection S8 of Transect 3 (Figure 8). The diffuser cap was one of the few very high relief features at depth. The large community of *Asterias* spp. on the cap may represent a transitional taxon on a substrate only recently introduced into the environment. The only other very high relief substrate at great depth was near the diffuser cap at Subsection S10. The population of *Asterias* spp. on that large boulder was much smaller (Figure 8).

The forgoing discussion described the importance of relief height, independent of water depth, in determining the distribution of some taxa. Thus, as in past studies, relief height should be included with water depth as a physical factor in tests for anthropogenic change. The distribution of *M. senile* (frilled anemone) in Figures 6 through 11 emphasizes the differences in boulder versus rock habitats. Thus, from Table 1, a reasonable transition diameter for distinguishing between high relief and low relief is 1 m. On the U.S. Pacific coast, Hardin *et al.* (1994) also defined high-relief as those hard-substrate features extending 1 m above the bottom.

3.2.3 Geographic Distribution

Given that water depth and substrate size are physical factors of interest, the task is now to specify transect subsections most representative of the four categories, deep high-relief, deep low-relief, shallow high-relief, and shallow low-relief. Again, the megafaunal community structure is used to define contiguous subsections where the substrate is typified by one of the four physical-factor categories and across-which megafaunal distributions are consistent. To aid in the selection of future hard-substrate monitoring sites, a dendrogram resulting from a numerical classification among transect subsections (Q mode) is presented in Figure 12. As expected, the highest Bray-Curtis similarities were often between adjacent subsections. Ten cluster groups were formed by contiguous subsections having high similarity.

For example, two cluster groups (T6-A and T6-B) formed along Transect T6 with respective Bray-Curtis similarities exceeding 0.78 and 0.70. Cluster Group T6-A includes Subsections S1 through S14 which were characterized by boulders and large rocks. These Subsections extended 625 m along the southeast portion of

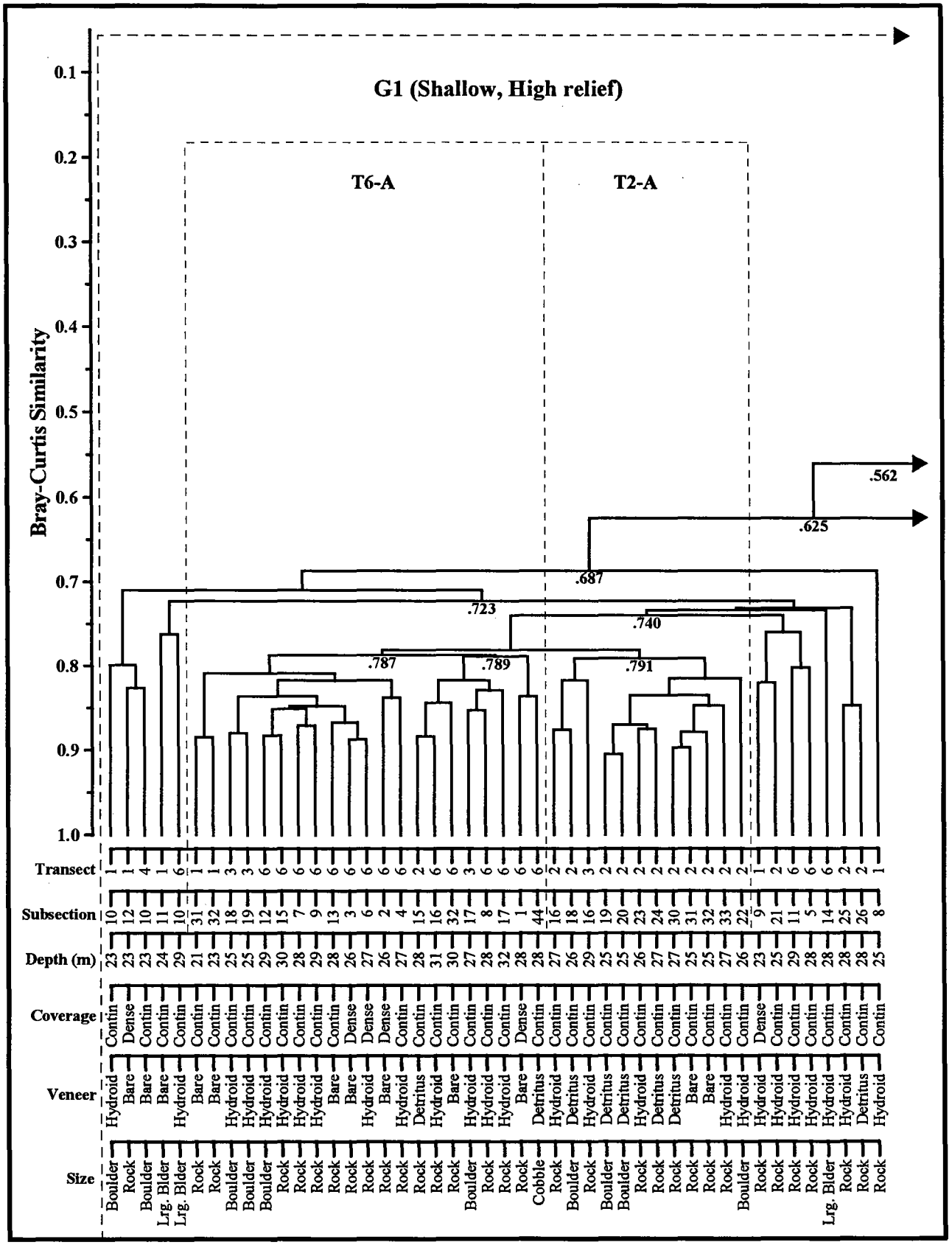

Figure 12. Dendrogram resulting from clustering (group average sorting) of Bray-Curtis similarity among transect subsections.

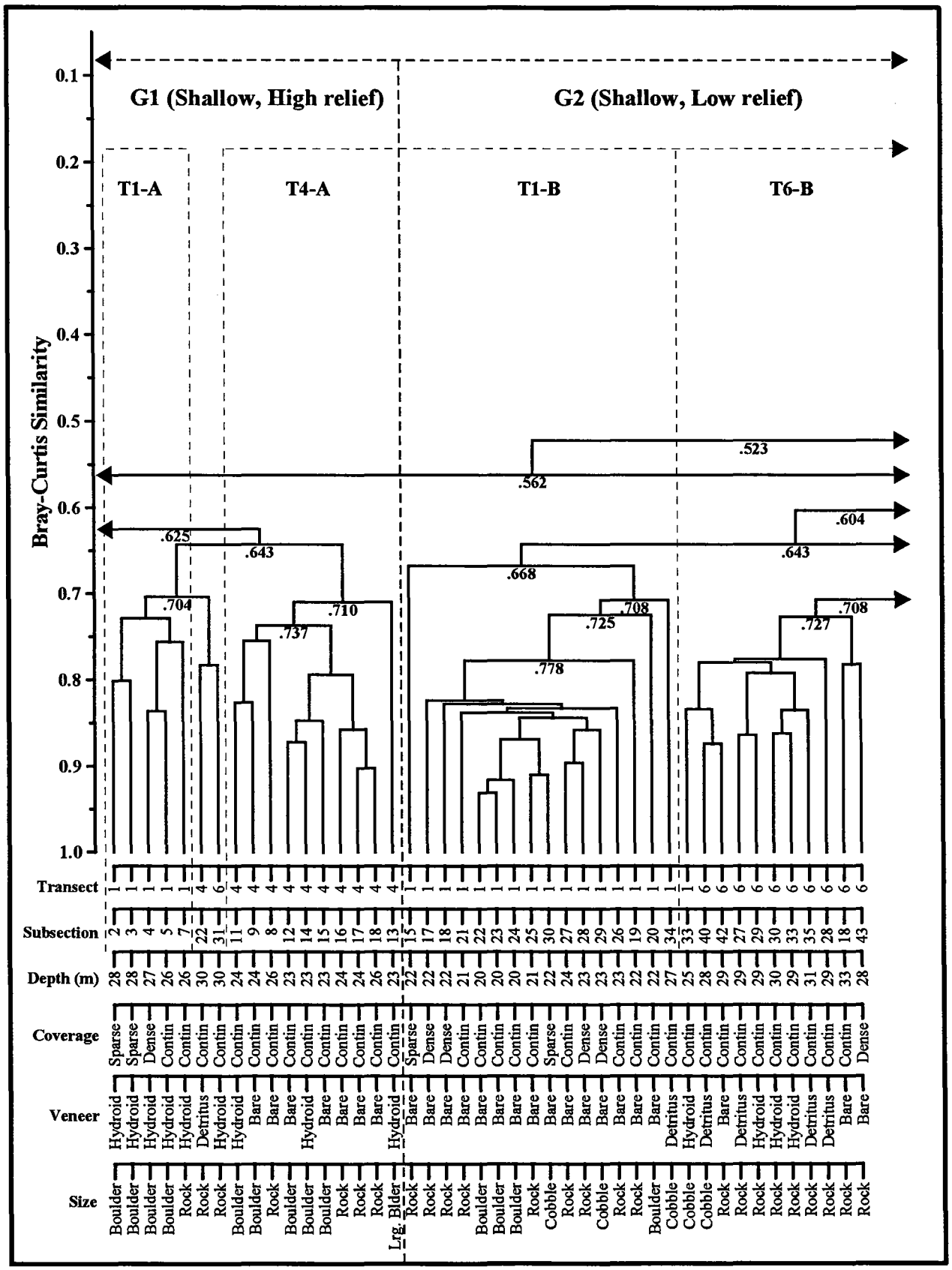

Figure 12 (continued). Dendrogram resulting from clustering (group average sorting) of Bray-Curtis similarity among transect subsections.

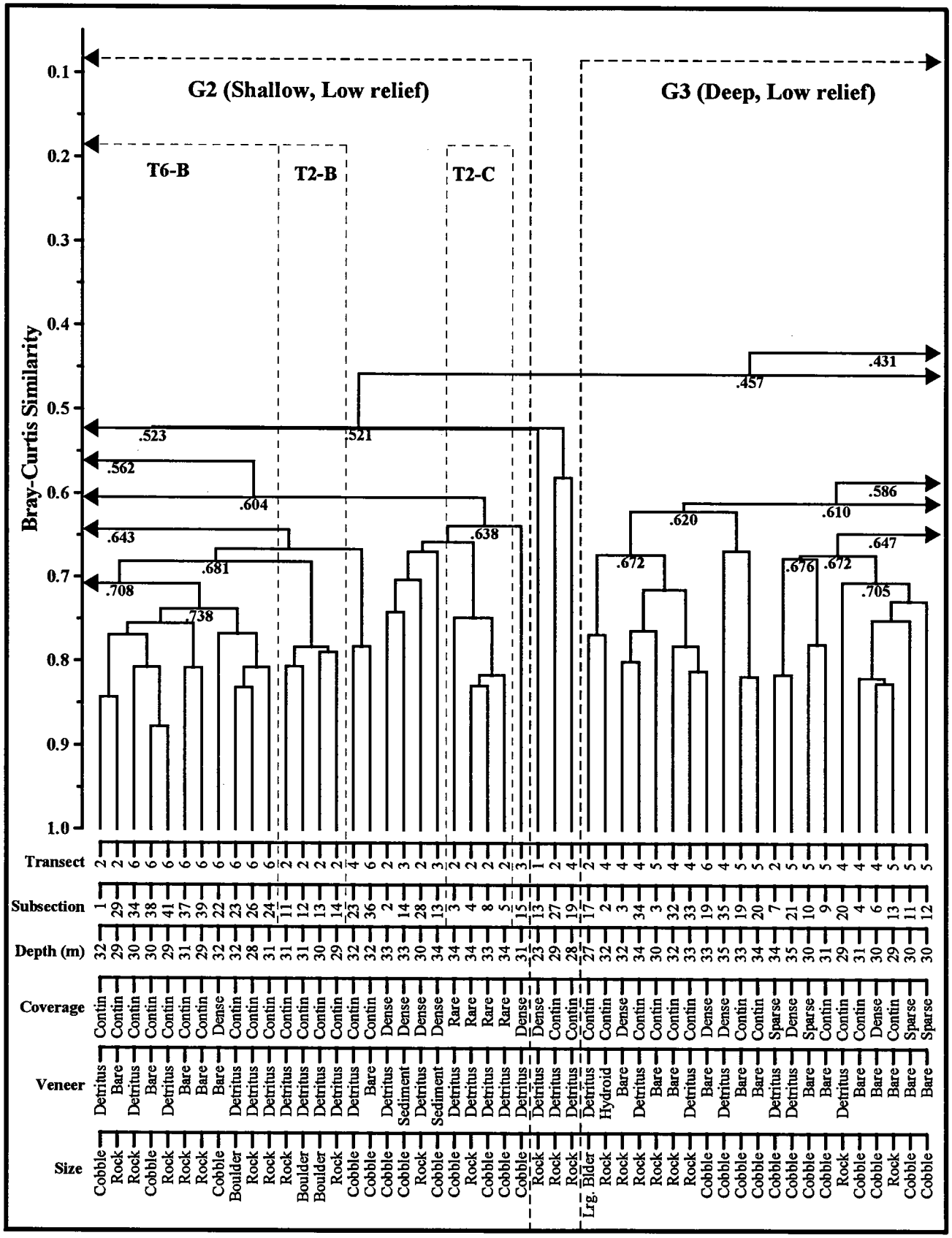

Figure 12 (continued). Dendrogram resulting from clustering (group average sorting) of Bray-Curtis similarity among transect subsections.

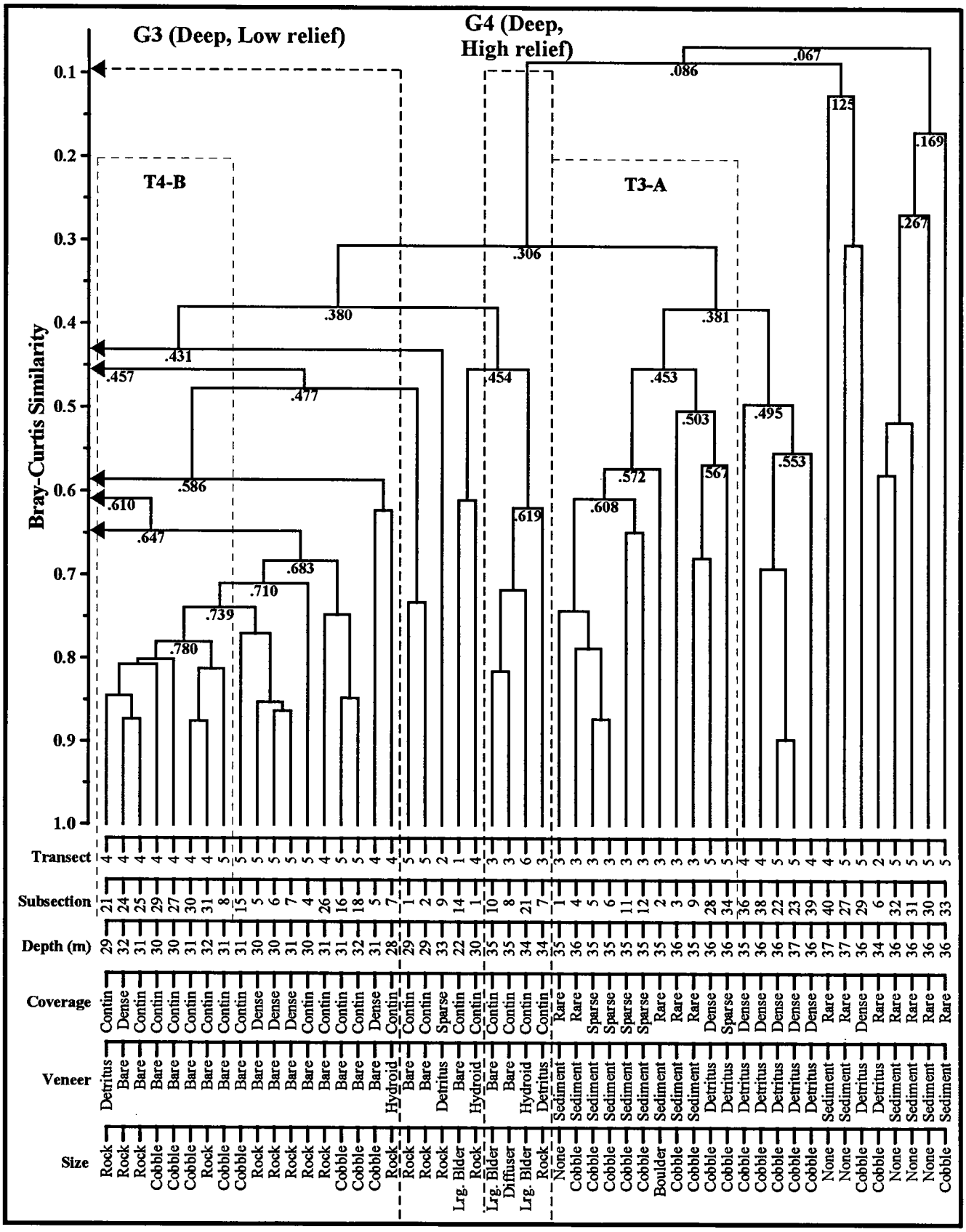

Figure 12 (continued). Dendrogram resulting from clustering (group average sorting) of Bray-Curtis similarity among transect subsections.

the Transect T6 which lies atop the drumlin immediately to the south of the diffuser cap corridor (Figure 1). In contrast, Cluster Group T6-B contained shallow low-relief features such as cobbles and small rocks (Figure 12). It included most Subsections between S25 and S45, and extended nearly 1 km along the northwest portion of T6. Analogous areas of contiguous subsections along other Transects clustered with high similarity as shown in Figure 12. At lower Bray-Curtis similarity, specifically a decision rule near B=0.6, these contiguous subsections formed cluster groups representative of the four combinations of physical factors. These are also indicated in Figure 12 as Major Cluster Groups G1 through G4.

Major Cluster Group G4 consisted of comparatively few transect subsections. This was a consequence of the paucity of deep high-relief features due to the regional geomorphology described previously. Indeed, one of the few deep high-relief features was artificially introduced into the deep environment. Diffuser cap number 23 was surveyed in Subsection S8 along Transect T3. Despite its relatively recent introduction, its megafaunal community clustered with that of other deep large boulders (Figure 12).

One cluster group (T3-A) of contiguous subsections along Transect T3, did not correspond to any of the major cluster groups. This cluster group covered Subsections S1 through S6 of Transect T3, which extended over deep sediments immediately north of the diffuser-cap corridor (Figure 1). Similarly, the megafaunal community within other subsections comprised mostly of deep sediments, did not compare with any of the four major cluster groups. These subsections exhibited the lowest similarity indices and are shown adjacent to Cluster Group T3-A at the end of the dendrogram. None are viable locations for hard-substrate sampling, but were included to investigate the character of existing (viz. Station S4) and potential infaunal sampling locations.

4.0 RECOMMENDATIONS

4.1 HARD-SUBSTRATE SITES

Sites recommended for future quantitative analyses of hard-substrate epifaunal communities are listed in Table 5. They are sorted by the four combinations of physical factors and list contiguous subsections indicative of similar megafaunal community structure as determined from Figure 12. Where applicable, cluster groups from Figure 12 are also indicated. The locations of the recommended sampling regions relative to the diffuser-cap corridor are shown in Figures 13 through 16 for each of the four combinations of physical factors. All contain sites that are both distant (>500 m) and close to the diffuser-cap corridor.

The recommended sampling sites do not include all possible sampling sites but were limited by the selection criteria described at the outset of this report. Other sites, potentially suitable for hard-substrate sampling, can be derived from the megafaunal database presented in the data report (Coats and Campbell, 1994). For example, the number and extent of deep high-relief sites (Figure 16) are limited compared to the sites representative of other combinations of physical factors. This group of recommended sites could be augmented by the isolated boulder located within the Subsection S2 of Transect T3 (*cf.*, Figure 8). During enumeration from video images, this boulder was not deemed of sufficient size to separate into a new subsection. Consequently, numerical classification indicated that the megafauna of this subsection was closely affiliated with other deep sedimentary sites within Cluster Group T3-A and not with the Major Cluster Group G4 indicative of high relief features (Figure 12). Other special cases also exist and additional analysis of the data may be warranted if the recommended sites are deemed insufficient or unsuitable.

4.2 NEAR-FIELD SEDIMENTARY SITES

Several regions of continuous sedimentary deposits of substantial extent were observed in the reconnaissance survey. These regions could potentially serve as soft-bottom sampling sites. One such region was successfully grab sampled at a site designated Station S4 in the soft-bottom benthic monitoring program of 1994 (Campbell, 1994). The broad extent of the sedimentary deposits without any indication of buried hard-substrate suggests that the deposits are deep and stable over time. Some are located in the extreme near-field, directly adjacent to the diffuser.

Three regions are particularly devoid of hard-substrate. The locations of these regions are listed in Table 6 and are shown in Figure 17. One set of contiguous subsections lies just north of the diffuser within a topographic low along Transect T3. Although these subsections include a single isolated boulder (Subsection S2 in Figure 8), they otherwise lack hard substrates. The estimated length of this sedimentary basin is listed as 175 m in Table 6, but it is likely that it covers a somewhat wider area. The region immediately north of Transect T3 was not surveyed but lies at a similar depth as the surveyed portion of the sedimentary basin. Similarly, Subsections S5 and S6 lie closer to the diffuser and were characterized by a sparse distribution of hard substrate. Thus, grab sampling may be possible at distances closer than 108 m (Table 6) to the diffuser caps as long as the rip-rap surrounding diffuser caps is avoided.

Table 5. Recommended hard-substrate sampling locations.

Substrate	Subsections	Cluster Group	First End Point	Second End Point	Length (m)	Mean Depth (m)	Closest Approach to Diffuser (m)
Shallow High Relief	T4(S8-S18)	T4-A	42° 23' 0.362" N 70° 47' 1.617" W	42° 22' 56.974" N 70° 47' 23.113" W	503	24	476
	T1(S1-S24)	T1-A	42° 23' 33.150" N 70° 48' 0.387" W	42° 23' 46.505" N 70° 48' 38.350" W	961	23	819
	T6(S1-S14)	T6-A	42° 22' 36.805" N 70° 46' 7.987" W	42° 22' 43.402" N 70° 46' 33.815" W	625	28	1168
	T3(S17-S20)		42° 23' 3.820" N 70° 47' 20.082" W	42° 22' 59.958" N 70° 47' 18.013" W	128	25	290
	T2(S15-S33)	T2-A	42° 23' 28.879" N 70° 47' 15.062" W	42° 23' 37.871" N 70° 47' 54.896" W	952	27	429
Shallow Low Relief	T1(S25-S35)	T1-B	42° 23' 46.505" N 70° 48' 38.350" W	42° 23' 53.271" N 70° 48' 57.942" W	494	24	1453
	T6(S26-S34)	T6-B	42° 22' 48.610" N 70° 46' 54.140" W	42° 22' 54.156" N 70° 47' 16.222" W	533	29	600
	T6(S38-S45)	T6-B	42° 22' 56.058" N 70° 47' 23.527" W	42° 22' 59.805" N 70° 47' 38.548" W	363	29	303
Deep Low Relief	T5(S4-S23)		42° 22' 47.793" N 70° 47' 2.820" W	42° 22' 34.416" N 70° 47' 31.788" W	781	32	868
	T4(S2-S6)		42° 23' 2.655" N 70° 46' 50.139" W	42° 23' 1.062" N 70° 46' 59.824" W	227	31	489
	T4(S23-S39)	T4-B	42° 22' 55.601" N 70° 47' 31.244" W	42° 22' 50.394" N 70° 48' 2.124" W	724	33	447
	T2(S1-S8)	T2-C	42° 23' 21.500" N 70° 46' 50.112" W	42° 23' 25.585" N 70° 47' 6.423" W	394	33	64
Deep High Relief	T6(S21-S25)		42° 22' 45.556" N 70° 46' 42.765" W	42° 22' 47.937" N 70° 46' 51.695" W	217	32	928
	T3(S8)	Diffuser	42° 23' 13.383" N 70° 47' 22.100" W	42° 23' 13.132" N 70° 47' 22.386" W	10	35	3
	T3(S10)		42° 23' 11.768" N 70° 47' 22.387" W	42° 23' 11.599" N 70° 47' 22.435" W	5	35	39
	T2(S12-S13)		42° 23' 25.577" N 70° 47' 9.462" W	42° 23' 27.107" N 70° 47' 13.398" W	102	30	298

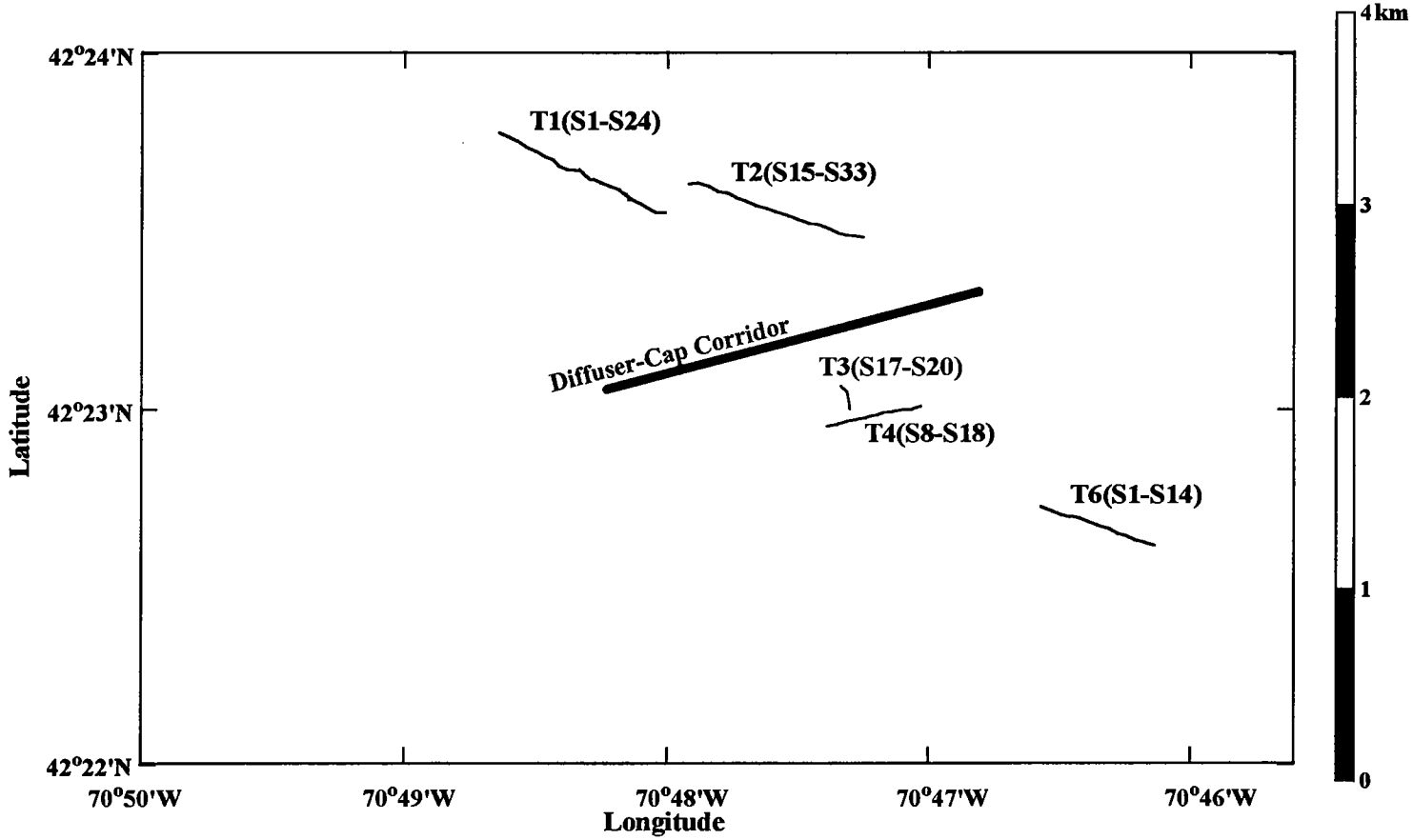

Figure 13. Location of shallow high-relief sites listed in Table 5. Numbers with a "T" prefix refer to transects and the "S" prefix indicates subsections.

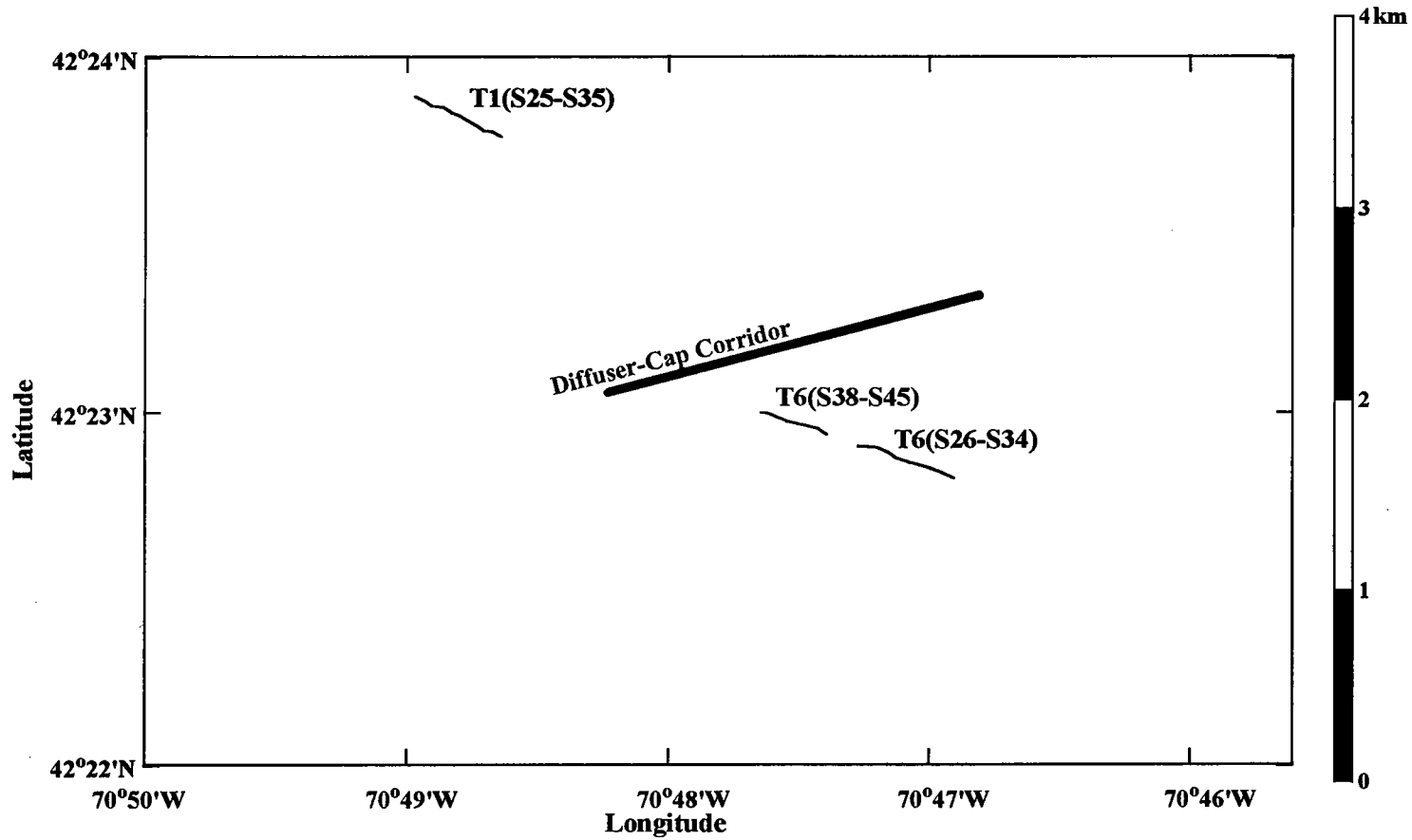

Figure 14. Location of shallow low-relief sites listed in Table 5. Numbers with a "T" prefix refer to transects and the "S" prefix indicates subsections.

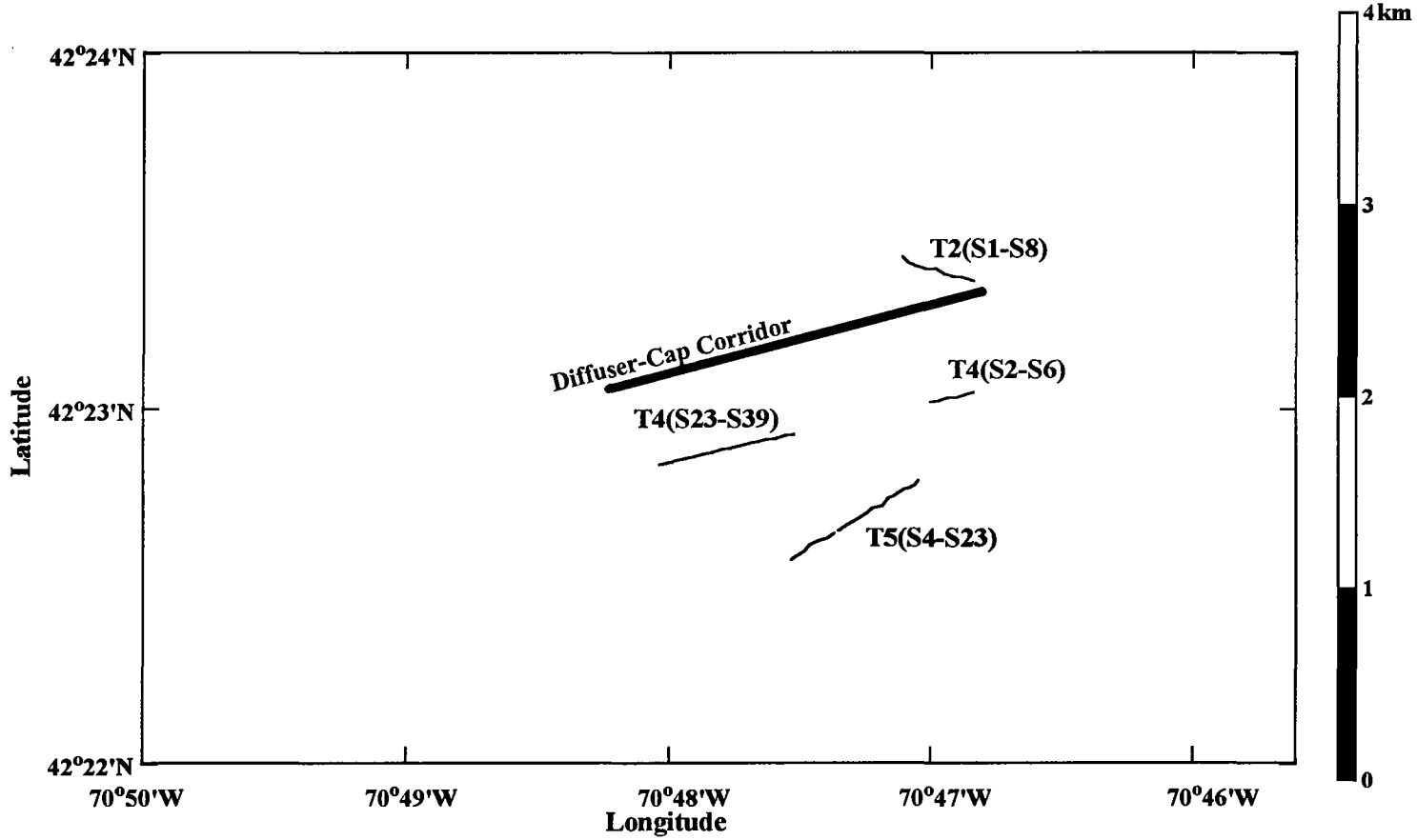

Figure 15. Location of deep low-relief sites listed in Table 5. Numbers with a "T" prefix refer to transects and the "S" prefix indicates subsections.

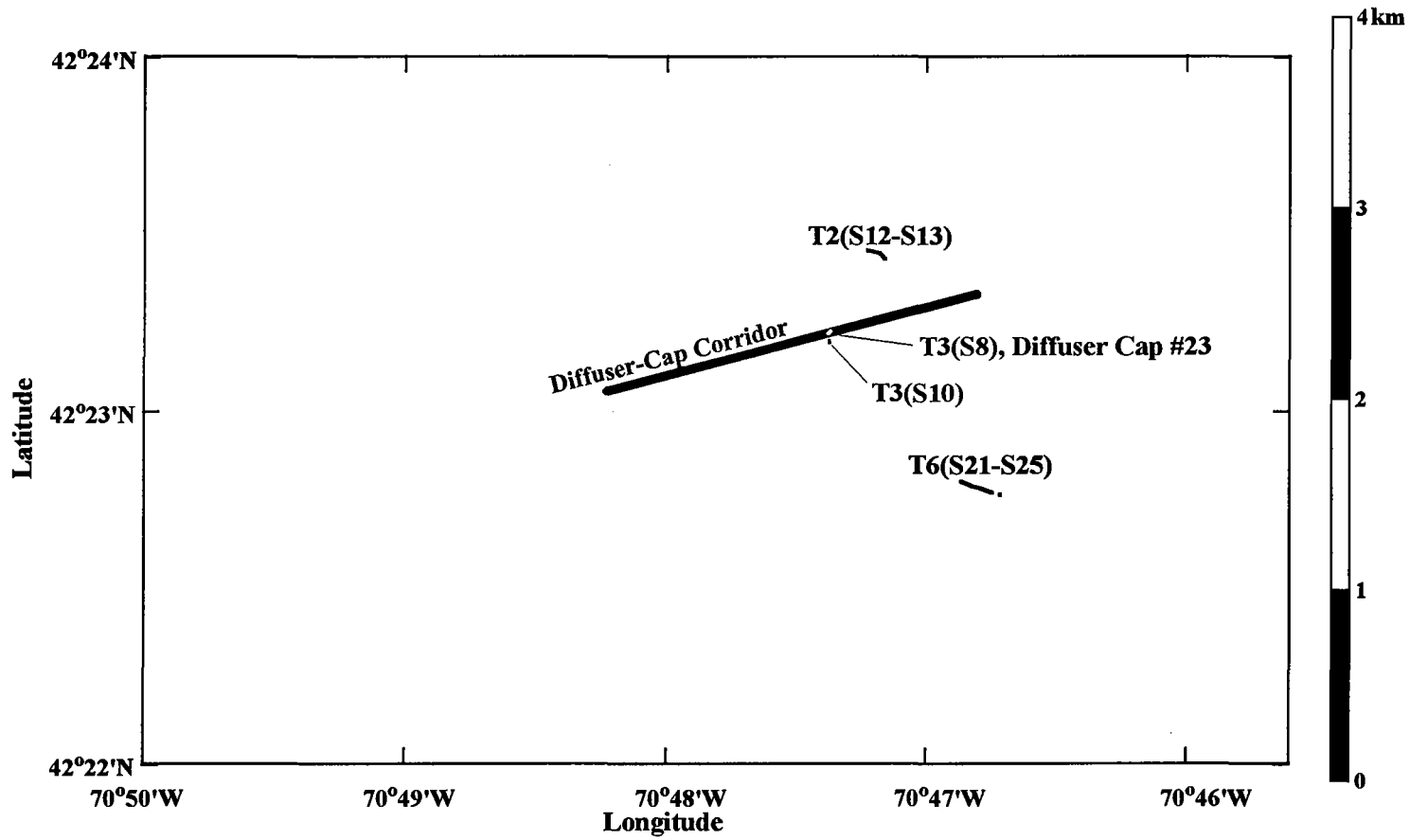

Figure 16. Location of deep high-relief sites listed in Table 5. Numbers with a "T" prefix refer to transects and the "S" prefix indicates subsections.

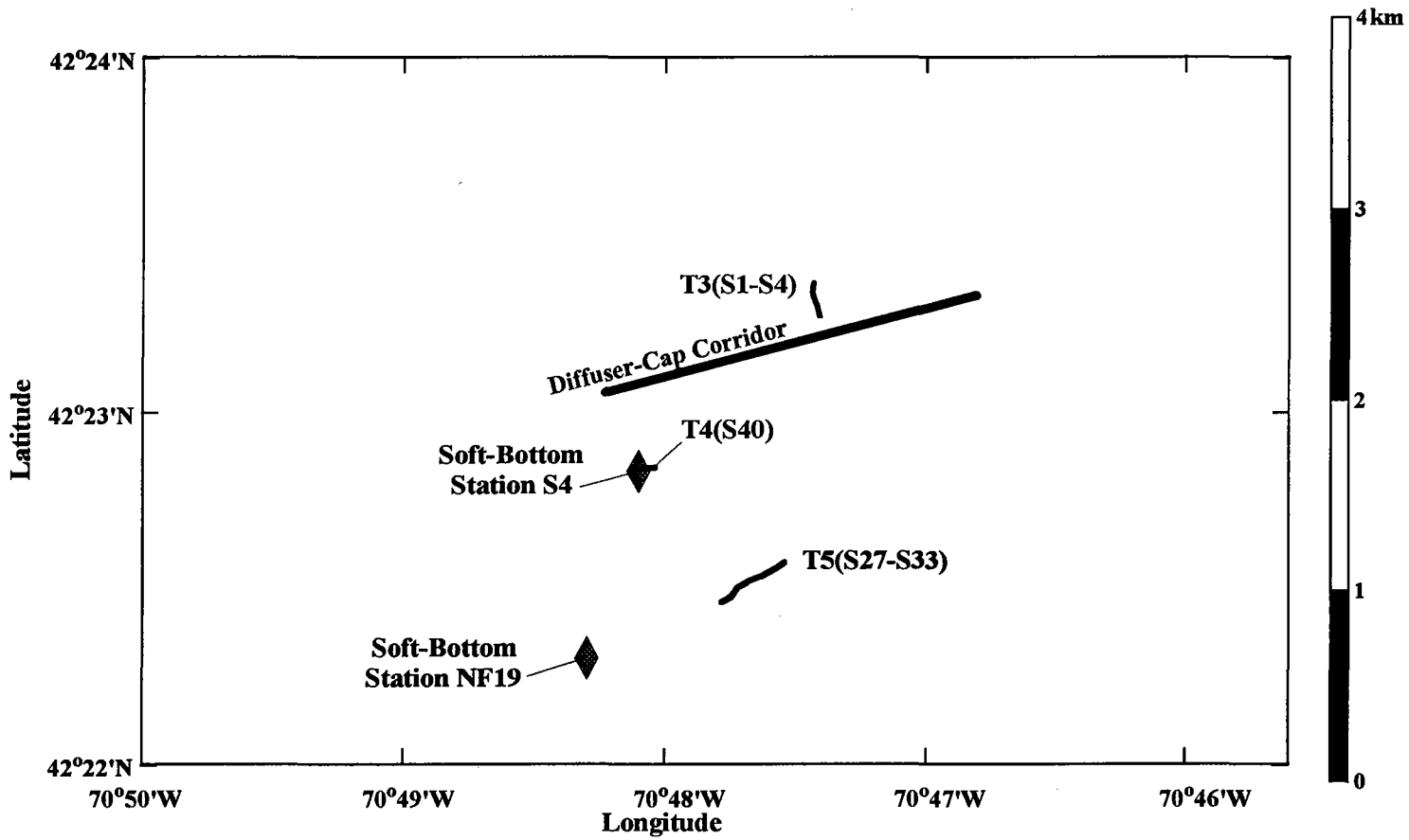

Figure 17. Location of deep sediment sites and the benthic infaunal sampling Stations S4 and NF19. Numbers with a "T" prefix refer to transects and the "S" prefix indicates subsections.

Table 6. Location of deep sedimentary deposits.

Subsections	First End Point	Second End Point	Length (m)	Mean Depth (m)	Closest Approach to Diffuser (m)
T3(S1-S4)	42° 23' 21.696" N 70° 47' 25.775" W	42° 23' 16.225" N 70° 47' 24.300" W	175	35	108
T4(S40)	42° 22' 50.394" N 70° 48' 2.124" W	42° 22' 50.072" N 70° 48' 5.007" W	67	37	447
T5(S27-S33)	42° 22' 34.242" N 70° 47' 32.156" W	42° 22' 27.535" N 70° 47' 46.518" W	303	36	1084

Another large area of deep sedimentary deposits was encountered along Transect T5, at Subsections S27 through S33. Again, the full lateral extent of the sediment is likely to be much larger than 303 m listed in Table 6. Indeed, these subsections lie at the end of the surveyed portion of Transect T5 where the planned ROV transit was stopped early specifically due to the lack of hard substrate (Figure 2). If the transect had continued, it would have passed close to the benthic infaunal Station NF19 (Figure 17) which has been successfully sampled in 1992 (Blake *et al.*, 1993) and in 1994 (Campbell, 1994). This suggests that the length of this sedimentary deposit extends beyond 1 km.

The other region of notable sedimentary deposits lies close to the benthic infaunal Station S4. Transect T4 was terminated at Station S4 so the latteral extent of sedimentary deposits is again indeterminate. However, Subsection S39, which lies immediately to the east of Subsection S40, was densely cobbled. This indicates that soft-bottom sampling near Station S4 is restricted to within approximately 67 m of its present location. The deep sediments of Subsection S40 supported an unusual megafaunal community, even among sedimentary deposits along other Transects. This difference is reflected in its low similarity index (0.125, near the end of Figure 12) and was due to a comparatively large population of *Urophycis* spp. (hake) residing in a complex of small burrows hollowed out of the fine-grained sediments.

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Nearshore Marine Biological Survey and Assessment Pinellas County Shore Protection Project Comprehensive Borrow Area Study

December 2002

Prepared for:
Jacksonville District
U.S. Army Corps of Engineers
400 West Bay Street
Jacksonville, FL 32202

Prepared by:
Dial Cordy and Associates Inc.
490 Osceola Avenue
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EXECUTIVE SUMMARY

Dial Cordy and Associates Inc. (DC&A) was contracted by the U.S. Army Corps of Engineers, Jacksonville District (Corps) to conduct a nearshore marine environmental baseline survey and report for the Pinellas County Shore Protection Project. This portion of the study focuses on the nearshore pipeline corridors and staging areas leading from potential offshore borrow areas. This work was done under contract GS-10F-0124L. Marine resources were mapped and documented with underwater still and video photography during July and August 2002.

Resources maps and summaries of habitat types delineated during the survey are reviewed in this report. Since the methods to be employed by the dredging contractors are not known, a complete impact assessment cannot be fully reviewed at this time. The information contained in this report should be used for planning of future beach nourishments and renourishments utilizing these offshore borrow areas and corridors. However, further surveying of the pipeline placement during construction, as well as equipment placement may need to be conducted before, during, and after construction to judge actual impacts to the marine resources present in each area.

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1.0 INTRODUCTION

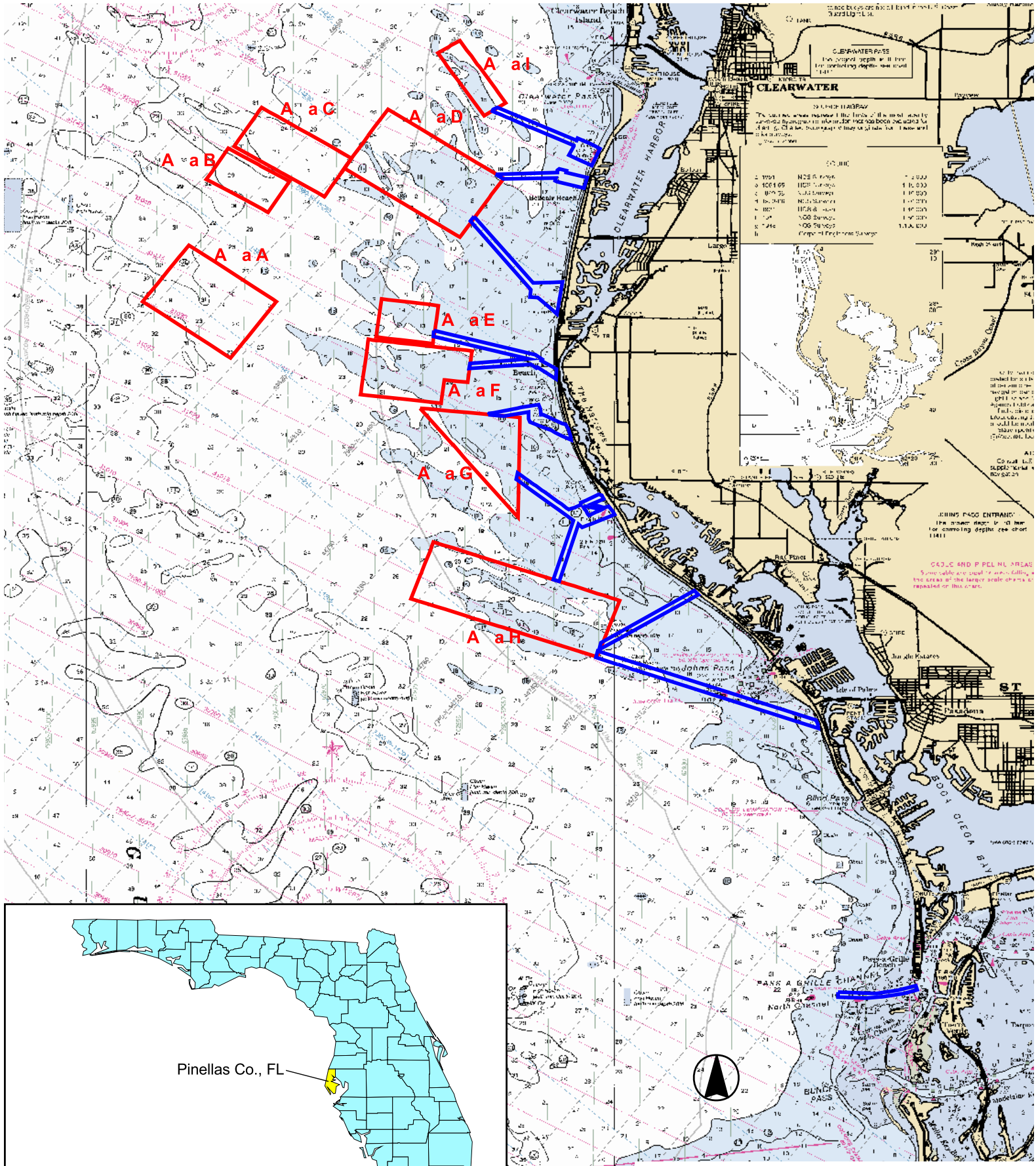
Dial Cordy and Associates Inc. (DC&A) was contracted by the U.S. Army Corps of Engineers, Jacksonville District (Corps) to conduct a nearshore marine environmental baseline survey and report for the Pinellas County Shore Protection Project. This portion of the study focuses on the nearshore pipeline corridors and staging areas leading from potential offshore borrow areas. This work was done under contract GS-10F-0124L.

1.1 Purpose and Need

Shoreline erosion and a lowered beach profile caused by storms, wave action, and currents have become a serious concern along Pinellas County barrier island beaches. As a means of controlling shoreline erosion and providing storm protection to these barrier islands fill material has been placed along the shorelines. The Pinellas County Shore Protection Project has historically obtained beach quality fill from inlet borrow areas and the Egmont Channel Shoal for nourishment of Pinellas County beaches. The use of the Egmont Channel Shoal is not always a cost effective option for nourishment of Pinellas County's beaches due to the logistical and cost constraints associated with moving material such a large distance (22 miles). To help offset some of the costs associated within renourishment activity nine offshore borrow areas have been identified for future use (Dial Cordy 2001). Bathymetry and side-scan sonar of nearshore marine habitats has also been performed (SeaSystems 2001). Identification of nearshore pipeline corridors and staging areas for construction equipment for these offshore areas is evaluated in this report. These nearshore areas required evaluation to document occurrence and quality of marine habitats to facilitate minimization of impacts.

1.2 Location

The project area is located in Pinellas County on the West coast of Florida, near the central portion of the Florida peninsula, approximately 25 miles west of Tampa. The sites investigated include the nearshore areas of Sand Key, Long Key, Treasure Island, and the Pass-a -Grille Channel (Figure 1).



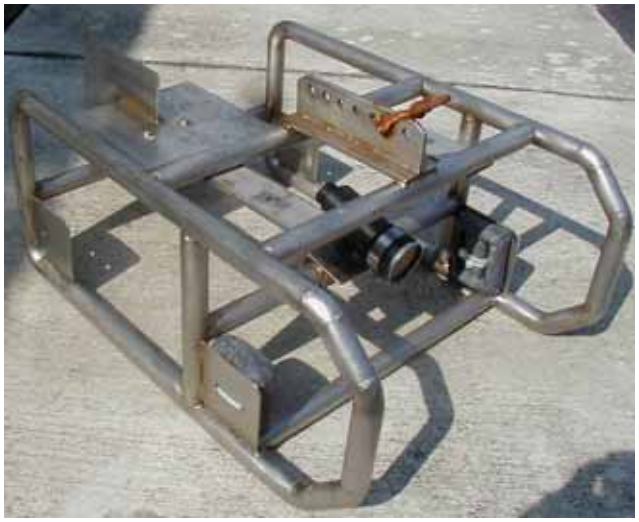
L n Map	
Ne e Mar e Bio l Sur y and Ass t Pi s Cou y Sho e Pro n Proje t C e Bor w Area Stu y	
S : 1 inch = 3 miles	D n By: MR
D : Oct , 2002	
DIAL CORDY AND ASSOCIATES INC	J 2
	F e 1

2.0 TECHNICAL APPROACH

DC&A conducted field investigations to locate, delineate, and characterize existing hardground and/or other benthic community resources within the proposed pipeline corridors and staging areas. Marine resources were mapped and documented with underwater still and video photography. The field survey was conducted during July and August 2002.

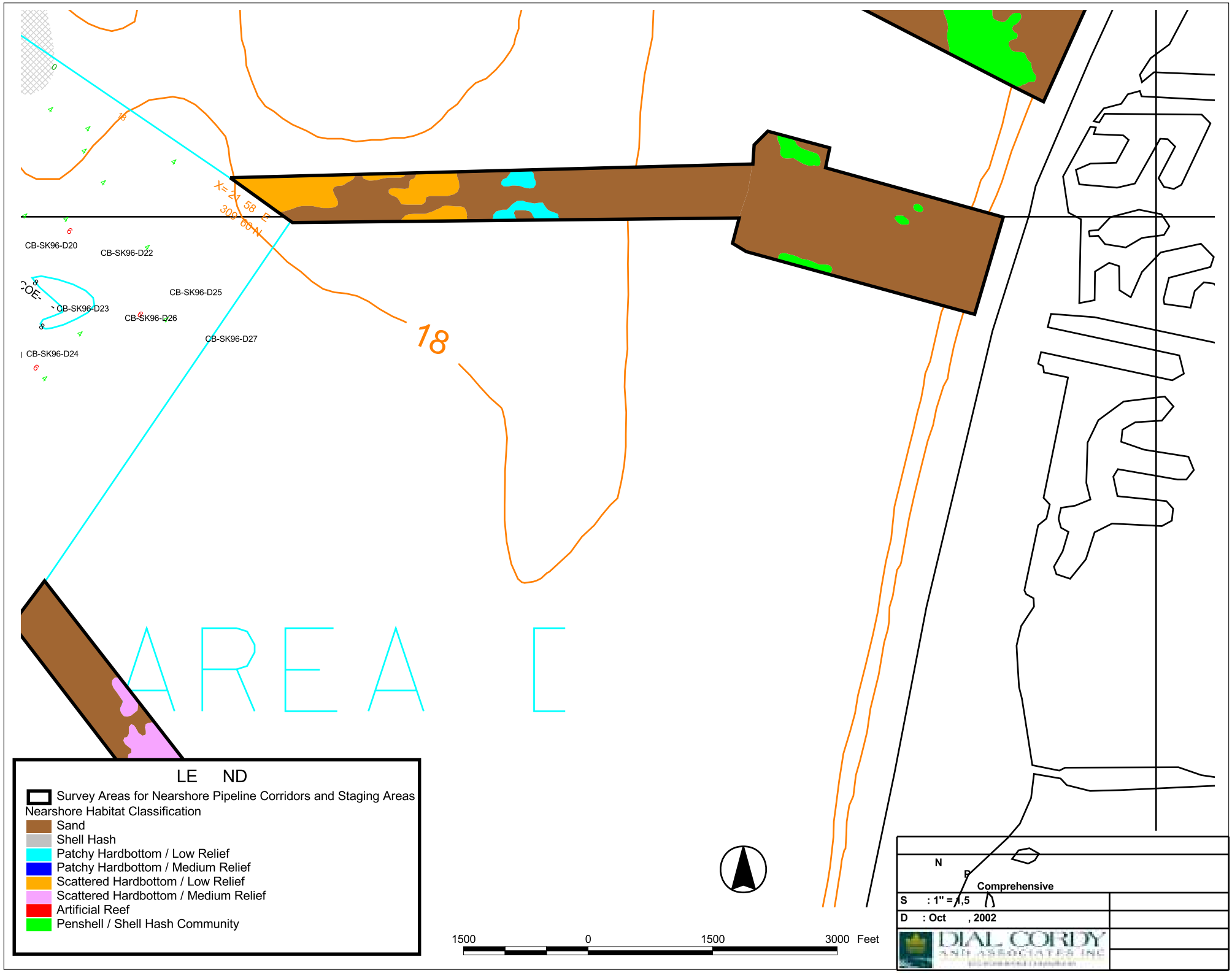
2.1 Towed Video Survey and Mapping

To identify and delineate any marine resources present within the proposed pipeline corridors and staging areas, a towed video survey was conducted. A towed video camera, in conjunction with Differential Global Positioning System (DGPS) and HYPACKMAX™ navigation software, was utilized (Photograph 1). Real time position of the camera was overlaid on the digitally recorded survey record. Transects were established within each area at 100-foot intervals. In total, over 160 nautical miles of transect lines encompassing over 2000 acres were surveyed (Figures 2-9).



Photograph 1 Towed video camera and sled used for mapping and assessment of marine resources offshore Pinellas County

The point at which each transect crossed a change in marine habitat (i.e. hardbottom, sand, etc.) was determined from video analysis. The points were then incorporated into a database and ArcView GIS™ was used to generate resource maps. Hardbottom was classified by percent of coverage and also vertical relief. Hardbottom classifications are shown in Tables 1 and 2.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CB-SK96-D22
CB-SK96-D25
CB-SK96-D23
CB-SK96-D26
CB-SK96-D27
CB-SK96-D24
18
AREA C
LE ND
Survey Areas for Nearshore Pipeline Corridors and Staging Areas
Nearshore Habitat Classification
Sand
Shell Hash
Patchy Hardbottom / Low Relief
Patchy Hardbottom / Medium Relief
Scattered Hardbottom / Low Relief
Scattered Hardbottom / Medium Relief
Artificial Reef
Penshell / Shell Hash Community
1500 0 1500 3000 Feet
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Comprehensive
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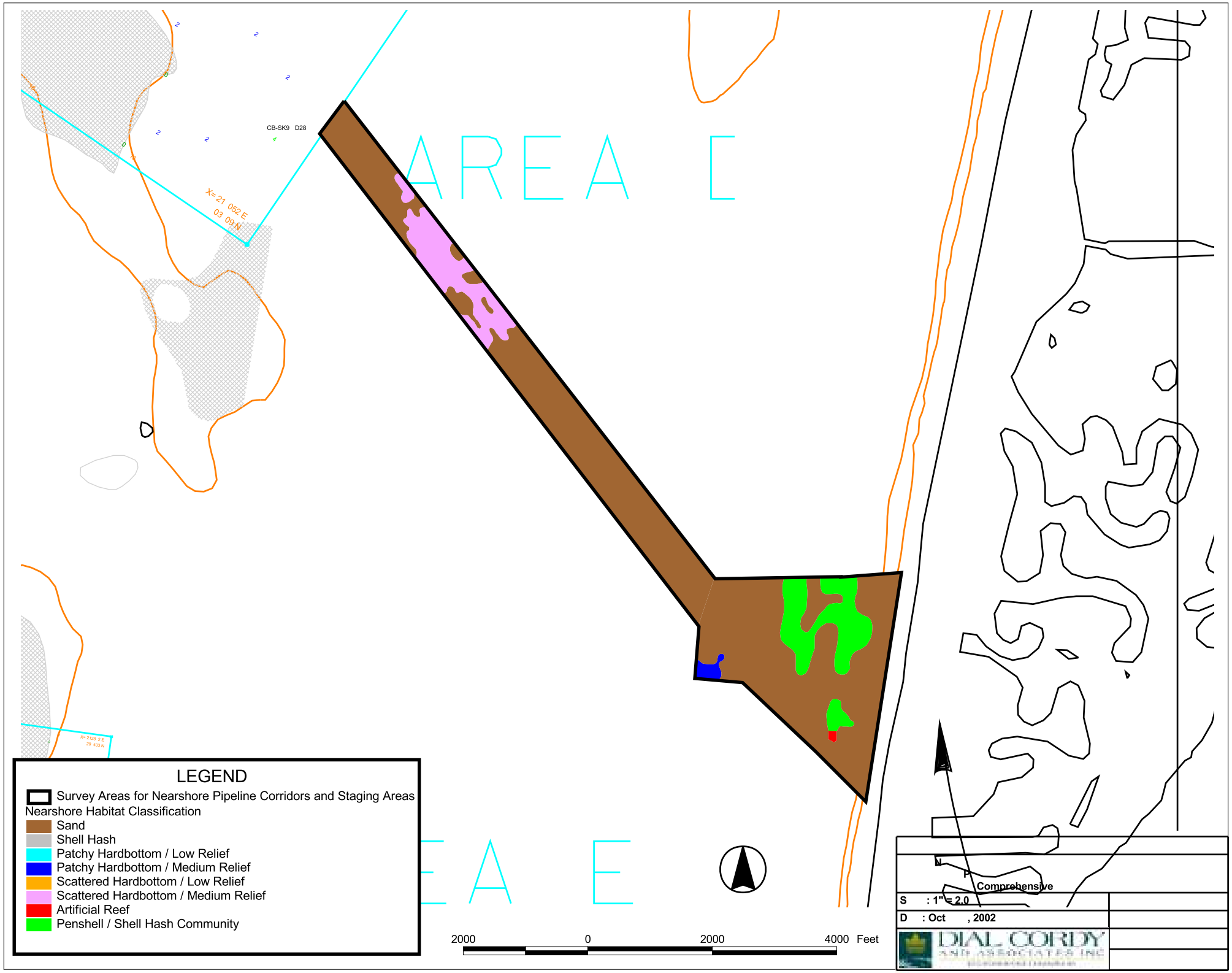
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Survey Areas for Nearshore Pipeline Corridors and Staging Areas
Nearshore Habitat Classification
Sand
Shell Hash
Patchy Hardbottom / Low Relief
Patchy Hardbottom / Medium Relief
Scattered Hardbottom / Low Relief
Scattered Hardbottom / Medium Relief
Artificial Reef
Penshell / Shell Hash Community
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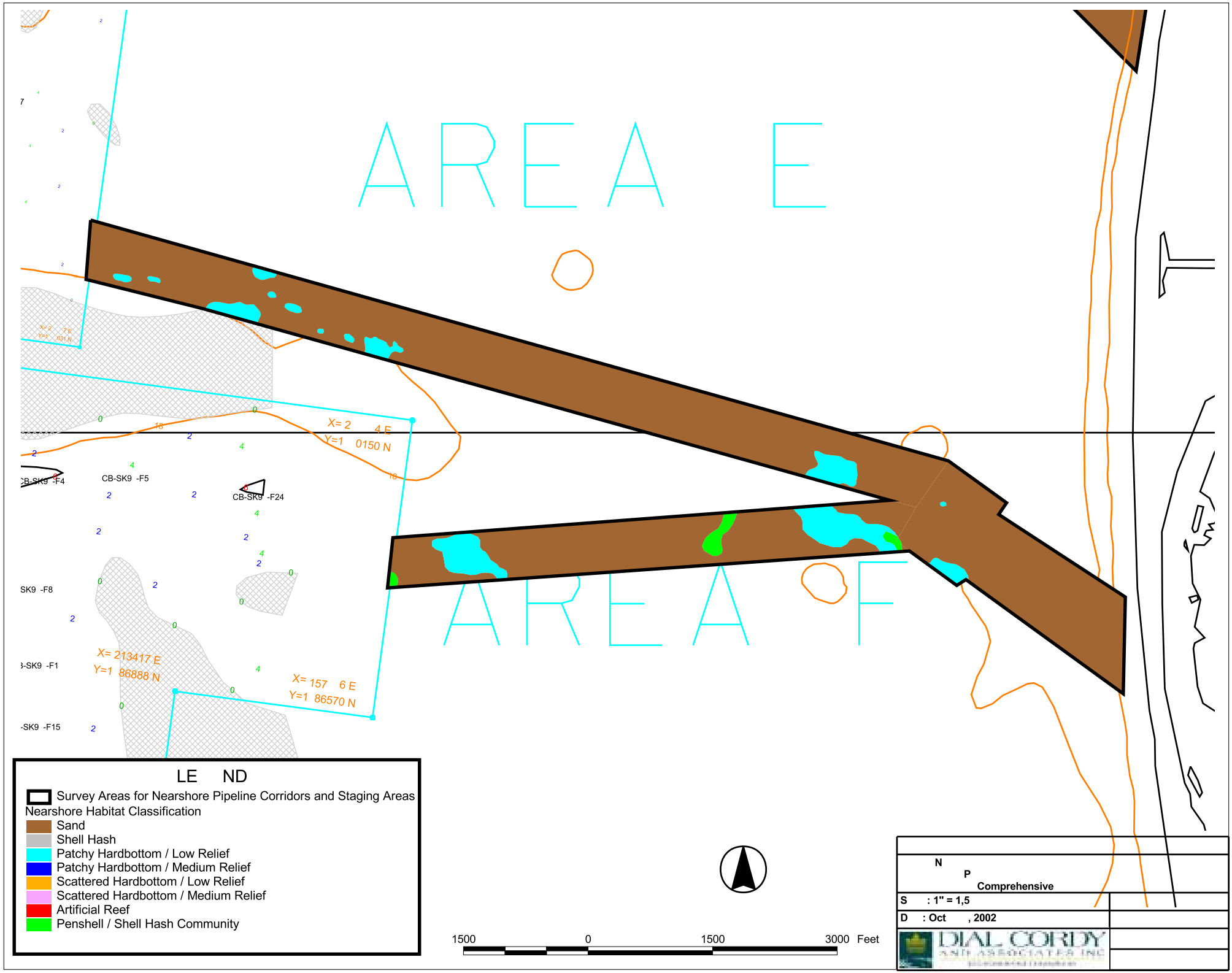
AND ASSOCIATES INC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AREA F
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CB-SK9 -F5
CB-SK9 -F24
SK9 -F8
-SK9 -F1
-SK9 -F15
X= 2 4 E
Y=1 0150 N
X= 213417 E
Y=1 86888 N
X= 157 6 E
Y=1 86570 N
LE ND
Survey Areas for Nearshore Pipeline Corridors and Staging Areas
Nearshore Habitat Classification
Sand
Shell Hash
Patchy Hardbottom / Low Relief
Patchy Hardbottom / Medium Relief
Scattered Hardbottom / Low Relief
Scattered Hardbottom / Medium Relief
Artificial Reef
Penshell / Shell Hash Community
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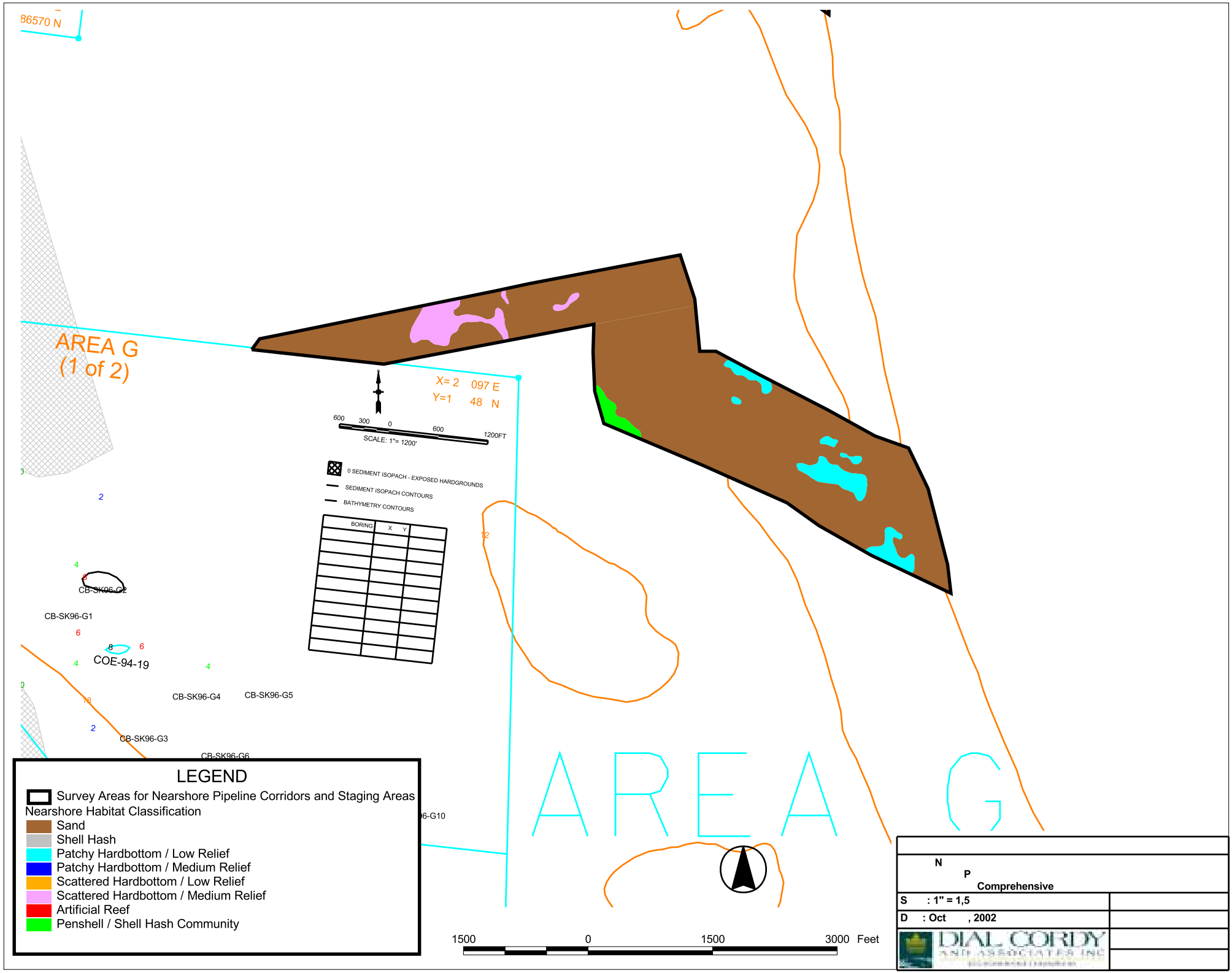
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BATHYMETRY CONTOURS
BORING
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CB-SK96-G1
COE-94-19
CB-SK96-G4
CB-SK96-G5
CB-SK96-G3
CB-SK96-G6
AREA G
LEGEND
Survey Areas for Nearshore Pipeline Corridors and Staging Areas
Nearshore Habitat Classification
Sand
Shell Hash
Patchy Hardbottom / Low Relief
Patchy Hardbottom / Medium Relief
Scattered Hardbottom / Low Relief
Scattered Hardbottom / Medium Relief
Artificial Reef
Penshell / Shell Hash Community
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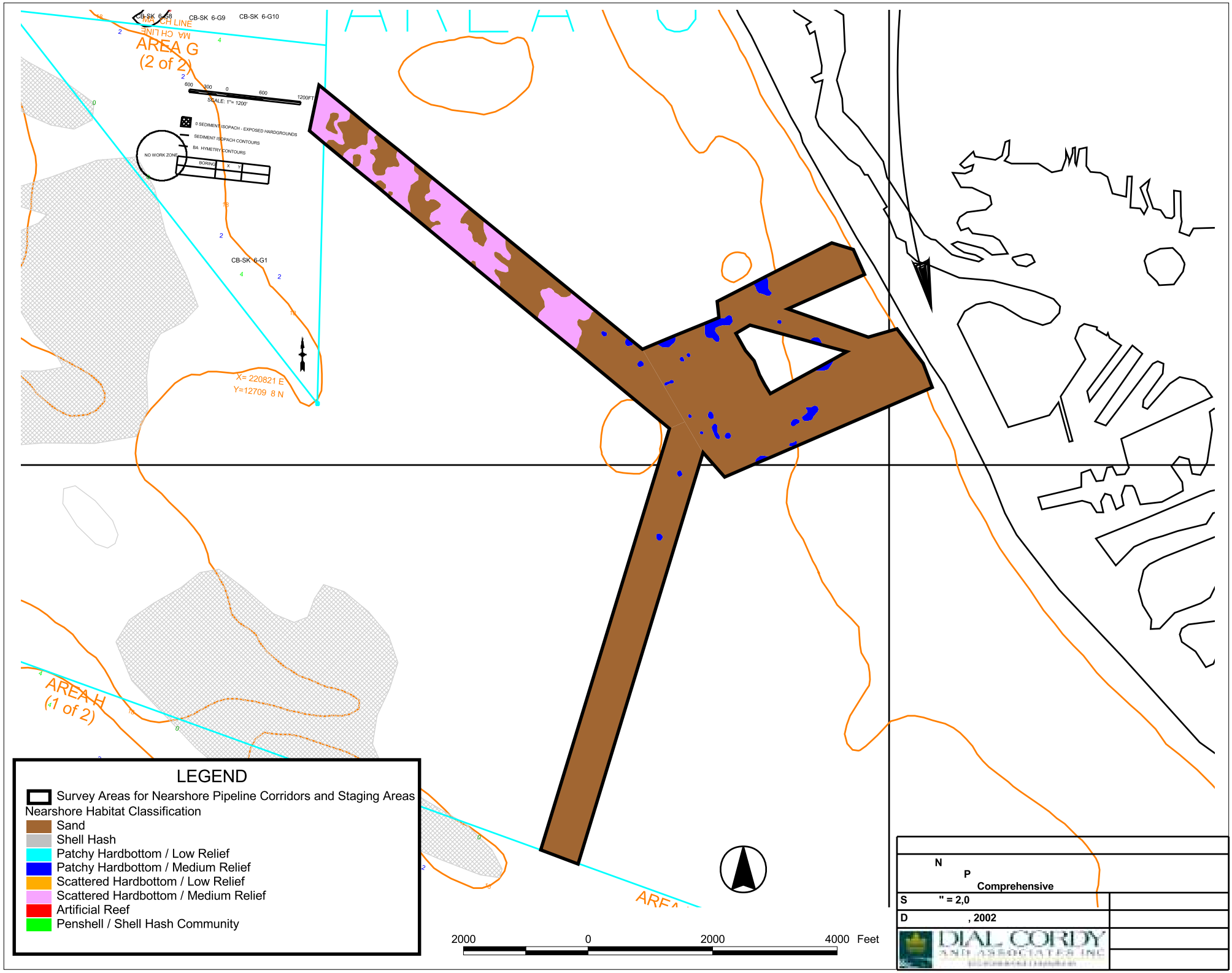
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CB-SK 6-G10
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SCALE: 1"= 1200'
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LEGEND
Survey Areas for Nearshore Pipeline Corridors and Staging Areas
Nearshore Habitat Classification
Sand
Shell Hash
Patchy Hardbottom / Low Relief
Patchy Hardbottom / Medium Relief
Scattered Hardbottom / Low Relief
Scattered Hardbottom / Medium Relief
Artificial Reef
Penshell / Shell Hash Community
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S " = 2,0
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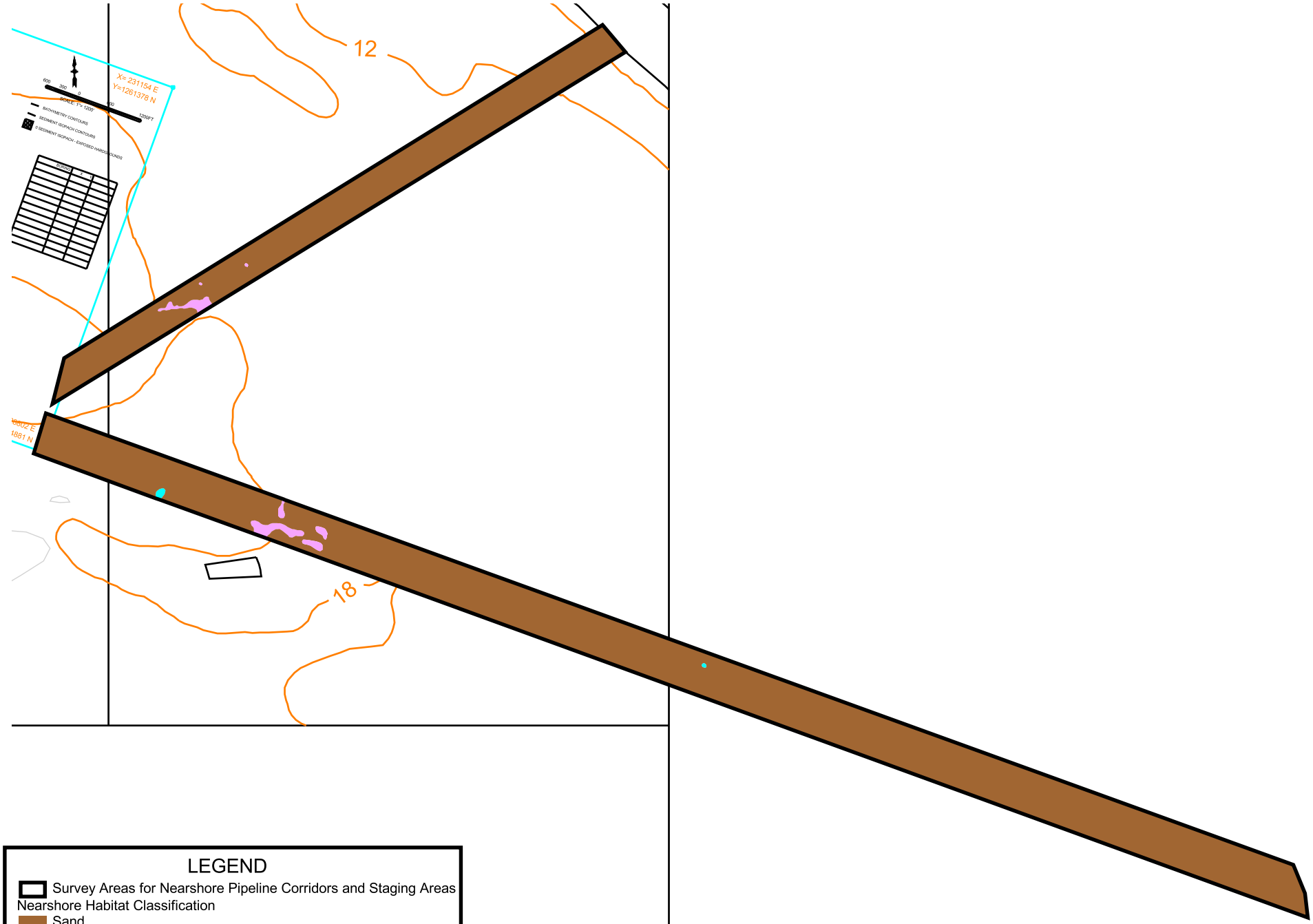

LEGEND

- Survey Areas for Nearshore Pipeline Corridors and Staging Areas

Nearshore Habitat Classification

- Sand
- Shell Hash
- Patchy Hardbottom / Low Relief
- Patchy Hardbottom / Medium Relief
- Scattered Hardbottom / Low Relief
- Scattered Hardbottom / Medium Relief
- Artificial Reef
- Penshell / Shell Hash Community

2500 0 2500 5000 Feet

N

S : 1" = 2,500'

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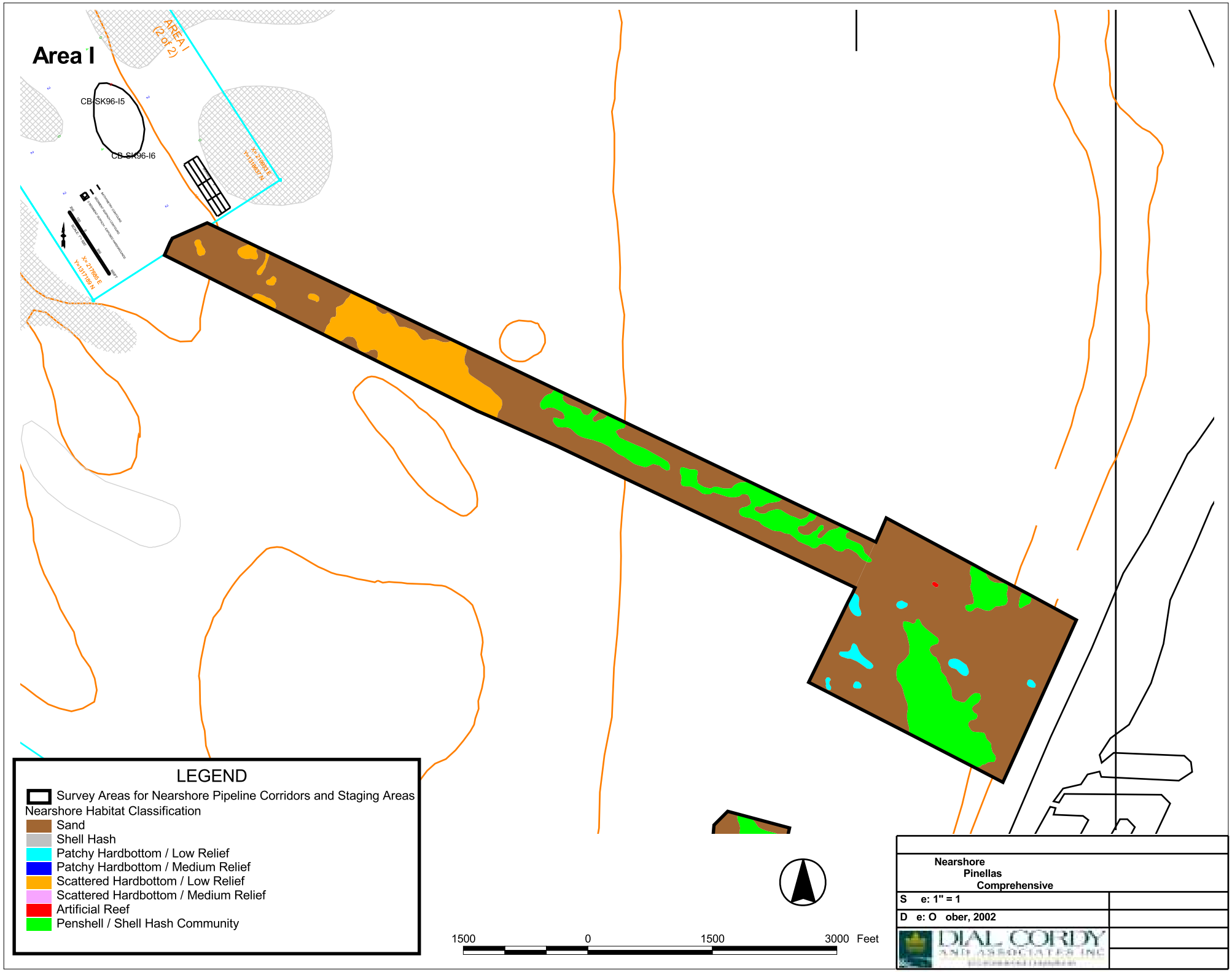
Area I
AREA I
(2 of 2)
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CB-SK96-I6
LEGEND
Survey Areas for Nearshore Pipeline Corridors and Staging Areas
Nearshore Habitat Classification
Sand
Shell Hash
Patchy Hardbottom / Low Relief
Patchy Hardbottom / Medium Relief
Scattered Hardbottom / Low Relief
Scattered Hardbottom / Medium Relief
Artificial Reef
Penshell / Shell Hash Community
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Nearshore
Pinellas
Comprehensive
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AND ASSOCIATES INC

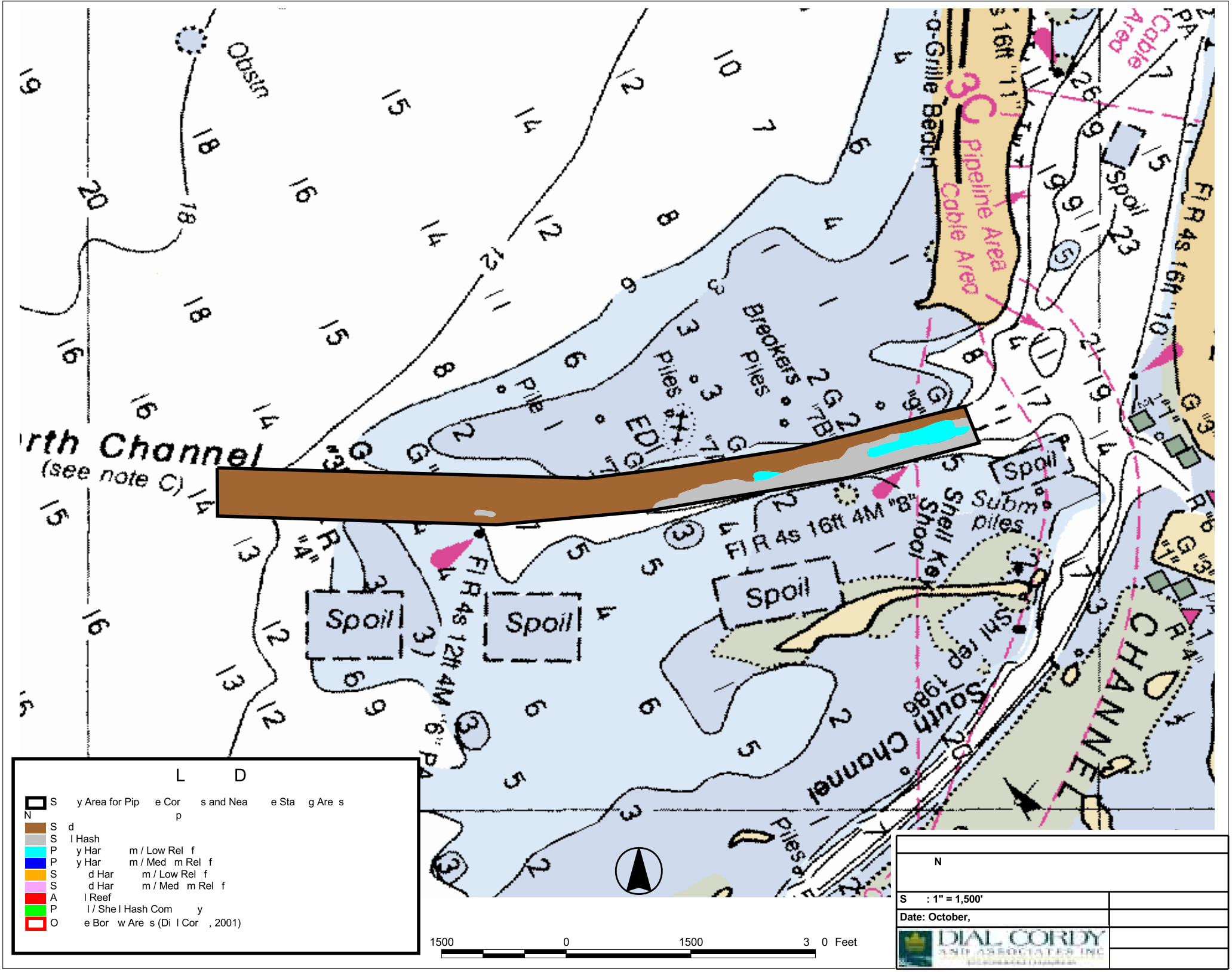

L D
S y Area for Pip e Cor s and Nea e Sta g Are s
N p
S d
S l Hash
P y Har m / Low Rel f
P y Har m / Med m Rel f
S d Har m / Low Rel f
S d Har m / Med m Rel f
A l Reef
P l / She l Hash Com y
O e Bor w Are s (Di l Cor , 2001)
N
S : 1" = 1,500'
Date: October,
DIAL CORDY AND ASSOCIATES INC
1500 0 1500 3 0 Feet
Obstn
Breakers
Piles
Pipeline Area
Cable Area
Spoil
Fl R 4s 16ft "10"
Fl R 4s 16ft 4M "8"
Fl R 4s 12ft 4M "6"
Shell Key Shoal
South Channel
Shl rep 1986
Subm piles
CHANNEL
rth Channel
(see note C)
Grille Beach

Table 1 Hardbottom Coverage Classification Used to Map Marine Resources

Classification	Percent Coverage
Penshell/Shellhash	Variable coverage in nearshore areas
Patchy	< 20% coverage
Scattered	20-75% coverage
Dense	>75% coverage

Table 2 Hardbottom Relief Classification Used to Map Marine Resources

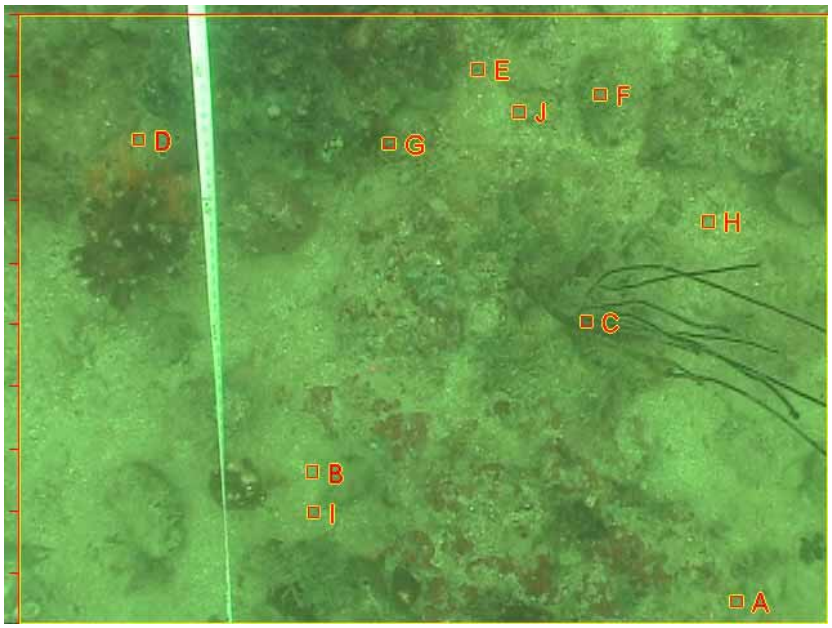
Classification	Relief (cm)
Low Relief	<30 cm
Medium Relief	30-100 cm
High Relief	>100 cm

2.2 Diver Survey and Characterization

In addition to the towed video survey, diver characterizations of existing habitats were also conducted. Representative habitat types, as determined from video analysis, were located and divers deployed to document the dominant invertebrate, fish, marine algae, and coral communities present within each of the survey areas.

2.2.1 Digital Image Analysis

The aim of the image analysis portion of the survey was to characterize the sessile biota (hard corals, soft corals, sponges and algae) located within each survey area. Within each survey area a 50 m transect was randomly laid to assess coverage of livebottom resources in the area. A diver with a digital video camera would then swim along the transect and collect a still image of the bottom type at every 5 m. Distance from the transect line was kept constant using a positioning device attached to the camera to allow for comparison between images. Images were then post processed and a random point analysis done on the images to assess percent coverage of habitat types (USGS BRD 2000). These images were viewed in Adobe Photoshop ® 5.0.2 and overlaid with 10 random dots on each photograph (Microsoft Excel® 2000) (Photograph 2). Percent coverage was estimated by counting the total number of dots covering each habitat type and data collected in a spreadsheet. The percent cover of each habitat type was then determined for each area and this summary percent cover used to map the respective habitats in each area.



Photograph 2 Sample grabbed digital image with point count dot overlay used in percent cover analysis.

Vertical relief and overall quality were also recorded. Still photographs and hand held video were also used to document the type and extent of living cover located within these areas.

2.2.2 Hardbottom Relief Assessment

Along each 50 m transect, relief measurements of hardbottom resources were also taken. At each 5 m sampling location, a graduated measuring rod was used to estimate the relief from the seafloor of significant marine resources. These measurements were averaged over each transect and the average relief of the survey area utilized for characterization and mapping.

3.0 MARINE RESOURCE CHARACTERIZATION

This section summarizes the results of the two-year comprehensive survey of offshore borrow areas, pipeline corridors and staging areas, as well as a review of pertinent literature.

3.1 Overview of Marine Resources

The area surveyed included areas offshore of Pinellas County, FL. These potential borrow areas, pipeline corridors and staging areas exist in water depths up to ten meters. Lyons and Collard (1974) describe these communities as areas of moderate wave energy with quartz sand and shell fragments extending offshore. Large temperate mollusks and echinoderms tend be the dominant faunal elements. In areas over 10 meters in depth, exposed rock substrate allows for the establishment of scleractinian, molluscan, crustacean, tunicates, and other species more common to shallower waters of south Florida (Smith 1974, Lyons and Collard 1974). Quartz sands, with biologically influenced carbonates present, also dominate the sediments within this area.

3.1.1 Fishes

Fishes off of the Gulf coast of western Florida are comprised of both reef and pelagic species. Many of the species present within this area are of commercial importance and addressed under the National Marine Fisheries Service (NMFS) Gulf of Mexico Fishery Management Council (GMFMC) Management Plan (GMFMC 1998). The fish assemblages in the area offshore of Pinellas County Florida and the Gulf of Mexico have been studied many times in the past. These studies have included reports which characterize the offshore and nearshore assemblages of fishes (Moe and Martin 1965; Saloman and Naughton 1979), cold stress of fishes on reef areas (Gilmore, et. al 1978; Bullock, et. al 1979), growth and reproduction (Shirripa and Burns 1997; Bullock, et. al 1996), and the impacts of fishing activities and predation (Pierce, et. al 1998; Nelson and Bortone 1996), as well as many others.

Moe and Martin (1965) collected over 2300 individual fishes from 41 species during sampling conducted nine separate locations offshore of Pinellas County. The most common fishes collected during this survey included sand perch (*Diplectrum fromosum*), pigfish (*Orthopristus chrysopterus*), silver perch (*Bairdiella chrysura*), spot (*Leiostomus xanthurus*), and pinfish (*Lagodon rhomboides*). Other species collected in this study included searobins (*Prionotus tribulus crassiceps* and *Prionotus scitulus latfirons*) and three species of flounder (*Etropus rimosus*, *E. crossotus atlanticus*, and *Syacium papillosum*).

Fishes of commercial and recreational importance within the eastern Gulf of Mexico include groupers and snappers. These species are included in the GMFMC snapper-grouper complex

fisheries management plan (1998). Species common to the area include yellowedge grouper (*Epinephelus flavolimbatus*) (Bullock, et. al 1996), gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*) (Schirripa and Burns 1997). Many of these species have been subjected to overfishing and stocks within the area have declined. This include red porgy (*Pargus pargus*), vermilion snapper (*Rhomboplites aurobens*), and other grouper species (*Epinephelus* sp.) (Roberts, et al. 1995).

Pelagic species also occur throughout the Gulf of Mexico in the nearshore and offshore waters. Major coastal pelagic families include Rachycentridae (cobia), Mugilidae (mullets), Pomatomidae (bluefish), Caranagidae (jacks), Scombridae (tunas and mackerels), Engraulidae (anchovies), and Carahahinidae (requieum sharks). Many of these pelagic species form large schools (e.g. jacks, mullet, mackerel, etc.), while others travel singly or in small groups (e.g. cobia). Distribution of these species can vary seasonally and usually depends on water column attributes that vary seasonally.

Fishes observed during diver and video surveys in this study are shown in Table 3. In total 22 species from 16 families were observed. Most species observed included small demersal species common to hardbottom areas. The most common species observed were sand perch (*Diplectrum fromosum*) and belted sandfish (*Serranus subligarius*); wrasses, in particular the slippery dick (*Halichoeres bivittatus*), were also very common in the study area. Other common fishes included searobins (*Prionotus* sp.) and menhaden (*Brevoortia sp.)*. Anecdotal observations of fishes during the survey included large schools of baitfish (Engraulidae and Clupeidae), sharks (Carahahinidae), seahorse (Sygnathidae), batfish (Ogcocephalidae) and mackerel (Scombridae).

Table 3 Fishes Observed Within Borrow Area During Diving Surveys

Scientific Name	Common Name
Haemulon sp.	Juv. Grunt
Equetus umbrosus	Juv. Highhat
Haemulon sciurus	Bluestriped Grunt
Haemulon chrysargyreum	Smallmouth Grunt
Haemulon melanurum	Cottonwick
Lutjanus griseus	Gray Snapper
Lachnolaimus maximus	Hogfish
Synodus intermedius	Sand Diver
Opsanus beta	Toadfish
Monocanthus sp.	Filefish
Halichoeres bivittatus	Slippery Dick
Diplectrum fromosum	Sand Perch
Archosargus probatocephalus	Sheepshead
Chaetodipterus faber	Spadefish
Calamus sp.	Porgy
Parablennius marmoreus	Seaweed Blenny

Scientific Name	Common Name
Diplodus holbrooki	Spottail Pinfish
Brevoortia sp.	Menhaden
Prionous sp.	Searobin
Echeneis naucrates	Sharksucker
Centropristis striata	Black Sea Bass
Epinephelus morio	Red Grouper
Sphoeroides testudineus	Checkered Puffer
Serranus subligarius	Belted Sandfish

3.1.2 Invertebrates

Benthic invertebrates associated with livebottom habitats along the eastern Gulf of Mexico include scleractinian, molluscan, crustacean, tunicates, octocoral, echinoderm, and porifera species. Many of these species are similar to species found in the more tropical waters of the Caribbean and south Florida reef tract. Lyons and Collard (1974) characterize the shallow shelf habitat offshore of Pinellas County as an area with sediments dominated by quartz sand and biogenically derived carbonates with exposed rock substrate. This substrate provides habitat for scleractinian, molluscan, crustacean and other invertebrate species.

Previous studies have identified species common to habitats offshore of Pinellas County (EPA 1981; CZR 1991; Child 1992; Posey et. al 1996). The species listed in these previous studies compares closely to species observed during this survey (Table 4). In total, over 40 dominant invertebrates species were observed from the diver and video surveys. There are many more cryptic and less obvious species present within these complex habitats.

Table 4 Dominant Invertebrate Species Observed During Borrow Area Surveys

Scientific Name	Common Name
Echinoderms	
Linckia guildingii	Common Comet Star
Astropecten articulatus	Beaded Sea Star
Echinaster spinulosus	Orange-Ridged Sea Star
Luidia clathara	Striped Sea Star
Luidia sp.	Sea Star
Luidia alternata	Banded Sea Star
Echinometra lucunter	Rock-boring Urchin
Lytechinus variegates	Variegated Urchin
Mollusks	
Pinna carnea	Penshell
Charonia variegata	Tritons Trumpet
Busycon contrarium	Lightning Whelk
Pleuroploca gigantean	Florida Horse Conch

Scientific Name	Common Name
Scleractin Corals	
Cladocora arbuscula	Tube Coral
Stephanocoenia mitchelinii	Blushing Star Coral
Isophyllia sinuosa	Cactus Coral
Siderastrea sp.	Starlet Coral
Solenastrea hyades	Knobby Star Coral
Scolymia lacera	Mushroom Coral
Phyllangia americana	Hidden Cup Coral
Manicina aereolata	Rose Coral
Montastrea annularis	Boulder Star Coral
Oculina robusta	Robust Ivory Tree Coral
Millepora alcicornis	Branching Fire Coral
Octocorals	
Eunicea succinea	Shelf-knob Sea rod
Eunicea calyculata	Warty Sea Rod
Plexaurella nutans	Giant Slit-Pore Sea Rod
Muricea laxa	Delicate Spiny Sea Rod
Muricea elongata	Orange Spiny Sea Rod
Pseudoterogorgia sp.	Sea Plume
Pterogorgia citrina	Yellow Sea Whip
Leptogorgia virgulata	Colorful Sea Whip
Sponges	
Cribrochalina vasculum	Brown Bowl Sponge
Xestospongia muta	Giant Barrel Sponge
Spheciospongia vesparium	Loggerhead Sponge
Ircinia sp.	Ball Sponge
Calyx podatypa	Dark Volcano Sponge
Anthosigmella varians	Brown Variable Sponge
Amphimedon compressa	Erect Rope Sponge
Pseudoceratina crassa	Branching Tube Sponge
Crustaceans	
Menippe mercenaria	Florida Stone Crab
Tunicates	
Clavelina sp.	Colonial tunicates
Family Didemnidae	Overgrowing Tunicates
Eudistoma sp.	Condiminium Tunciate

3.1.3 Marine Algae

The marine algae present within the areas offshore of Pinellas County are extremely diverse. Phillips, et al. (1960) identified 95 taxa of algae within areas of similar depth in this area. Dominant algal species observed during this and other studies includes *Caulerpa* sp., *Halimeda* sp., *Udotea flabellum*, *Sargassum* sp., and *Rhipocephalus phoenix* (Phillips, et al. 1960; EPA 1981; CZR 1991).

3.1.4 Other Vertebrates

Other vertebrate species, which utilize these offshore habitats, include many threatened and endangered species. The Gulf of Mexico is within the range of five species of sea turtle, the West Indian manatee (*Trichechus manatus*), and up to 28 cetacean species. Of these, four species of sea turtle, the manatee, and one cetacean, the bottlenose dolphin (*Tursiops truncatus*), occur within the study area.

3.1.4.1 Sea Turtles

Four species of sea turtle commonly occur within the area around Pinellas County (Meylan, et al. 1999; EPA 1981). These are the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), Kemp's ridley (*Lepidochelys kempii*), and the hawksbill (*Eretmochelys imbricata*). The loggerhead is listed as threatened and the other three species are listed as endangered. Loggerhead turtles represent most of the sea turtles present in the Pinellas County area. Data collected on sea turtle nesting in the area shows that the majority of the nests within this area consist of loggerhead nests (Table 5). Of the 279 nests observed on Pinellas County beaches in 2000, 278 were loggerhead nests and all 195 nests in 2001 were loggerhead. The only other nesting activity reported was one green turtle nest. In 2000, there was one reported green turtle nest and in 2002, two Kemp's Ridley nests were found on Sand Key (FMRI 2002). All turtles observed during this survey were loggerhead turtles; which were seen with regular consistency while conducting the survey. Stranding records within the Pinellas County area also confirmed that loggerhead turtles are the most numerous species.

Table 5 Summary of Loggerhead Sea Turtle Nesting From 1988-2000

Year	Beach Length Surveyed	Number of Nests
1988	69.5	56
1989	63.2	92
1990	62.1	144
1991	67.3	175
1992	63.3	142
1993	42.7	105
1994	52.6	138
1995	58.8	229
1996	49.1	223
1997	58.8	181
1998	52.3	233
1999	62.6	172
2000	62.6	279
2001	62.6	195

Source: Florida Marine Research Institute 2002

3.1.4.2 Marine Mammals

Marine mammals commonly present within the waters nearshore and offshore the study area include manatee and bottlenose dolphin. Bottlenose dolphins were commonly observed while conducting this survey. As many as 15 dolphins were observed at one time in the areas adjacent to the offshore borrow areas. Weigle (1990) documented that at least three distinct herds of dolphin are common within the Lower Tampa Bay area. This includes as many as 246 individual animals. Many of the dolphins observed may have been transient in nature. However, 75 individuals were observed on more than one occasion.

West Indian manatees also utilize habitats within the study area. Manatees inhabit both fresh and saltwater and may be encountered in canals, rivers, estuaries, bays, and on occasion have been observed as far as 6 km off the Florida Gulf coast (USFWS 1996). Aerial surveys indicate that as many as 190 manatees may use Tampa Bay (Ackerman 1995). Surveys show that over 900 manatees inhabit the west coast of Florida. The highest concentrations of manatees along Florida's Gulf coast exists in Citrus, Levy, Lee, and Collier Counties. Data suggest that of the manatees living in the Tampa Bay area, most occur within the bay where water temperatures are more stable year round. During aerial surveys in 1992, only 15 manatees were surveyed in the eastern portion of Tampa Bay (Akcerman 1995). Examination of the manatee mortality data for Pinellas and Hillsborough Counties shows that from January 2000-October 2001 a total of 27 manatee deaths were reported. The majority of these deaths involved perinatal, cold stress, or other natural causes.

3.1.5 Hardbottom and Livebottom Characterization

Hardbottom and livebottom within each of the survey areas was characterized for mapping and impact assessment. A summary of the results for each area is discussed in this section.

3.1.5.1 Digital Image Analysis

The aim of the image analysis portion of the survey was to characterize the sessile biota (hard corals, soft corals, sponges, and algae) located within each survey area. A total of 132 photographic quadrats were collected and analyzed. Overall, the mean coverage of living resources within all areas was 26.7 percent. A summary breakdown of means for each coverage classification is shown in Table 6. The major cover types within each area surveyed were sponges and macroalgae. Hard corals accounted for the lowest percentage living cover types identified with 0.7 percent.

Table 6 Summary of Mean Percent Cover For Each Classification Category From Image Analysis For All Areas Surveyed

Classification	Mean Cover (%)	Standard Deviation (n=132)
Coral	0.7	0.7
Gorgonians	4.2	5.5
Sponges	10.6	10.5
Macroalgae	9.8	6.2
Other, Live	1.4	3.4
Sand, Rubble	72.6	17.4
Unknown	0.7	0.7

3.1.5.2 Relief

Relief measurements within each survey area were averaged to obtain the mean relief within each area. These mean relief numbers were then used during the mapping of each area to develop a characterization of each area. A summary of mean relief within each area is shown in Table 7.

Table 7 Summary of Mean Relief From Diver Characterization

Survey Area	Mean Relief (cm)	Standard Deviation (n=11)
Area D South Site 1	39	6.1
Area D South Site 2	20.9	15.6
Area D	9.5	7.2
Area D Staging Area	3.9	3.6
Area E	1.4	3.2
Area F	12.2	13.1
Area F Staging Area	7.7	17.7
Area G North	20	22.5
Area G South	23.6	22.6
Area H	32.2	28.4
Area I	23.2	11.7

The extremely variable hardbottom distribution within each area accounts for the deviations in relief within each area. Outcroppings of limestone covered in living bottom interspersed with patches of open substrate are common in these areas. This mosaic of habitats creates communities of hardbottom/livebottom within these areas. Penshell/shellhash communities in these nearshore locations characterized survey areas with particularly low relief.

3.2 Pipeline Corridors

This section contains a description of marine resources located within each potential pipeline corridor surveyed. A summary of hardbottom resources within each pipeline corridor is shown in Table 8.

Table 8 Summary of Marine Resource Cover Types Within Each Area Surveyed

	Acres						
Corridor Survey Areas	**Sand**	**Penshell /Shellhash**	**Patchy Low Relief**	**Patchy Medium Relief**	**Scattered Low Relief**	**Scattered Medium Relief**	**Shellhash**
Area D north	58.9	------	4.0	------	17.4	------	------
Area D south	117.6	------		------	------	29.9	------
Area E	149.1	------	10.2	------	------	------	------
Area F	69.6	3.1	15.2	------	------	------	------
Area G north	58.1	------	------	------	------	7.9	------
Area G south	65.2	------	------	0.6	------	50.1	------
Area H north	159.3	------	------		------	2.7	------
Area H center	103.1	------	------	0.4	------	------	------
Area H south	418.4	------	0.7	------	------	5.5	------
Area I	80.7	20		------	27.8		------
Pass-a-grille	75.8	------	4.6	------			16.2
Staging Area Survey Areas							
Area D north (R62-R-63)	86.2	4.3	------	------	------	------	------
Area D south (R-74-R-78)	132.7	32.9	------	2.7	------	------	------
Area EF (R-84-R-86)	66.4	0.1	1.9	------	------	------	------
Area G north (R-91-R-93)	125.3	2.6	9.9	------	------	------	------
Area G south (R-99-R-103)	172.4	------	------	8.2	------	------	------
Area I (R-58-R-61)	99.4	27.0	3.2	------	------	------	------

3.2.1 Borrow Area D

Borrow Area D is located in the northern extent of the survey area offshore Pinellas County (Figure 1) (Dial Cordy 2001). Two potential pipeline corridors were identified from prior investigations and surveyed for marine resources.

3.2.1.1 North Corridor

Marine resources in the north corridor of Area D are shown in Figure 2. Marine resources located in this potential pipeline corridor include 17.4 acres of scattered/low relief hardbottom. These resources are located along the western extents of the corridor near the borrow area. An additional 4.0 acres of patchy/low relief hardbottom is also located in this corridor. Overall the hardbottom within this corridor is variable in its distribution and very low relief.

3.2.1.2 South Corridor

The south corridor for Area D contains a total of 29.9 acres of hardbottom habitat. These marine resources are located primarily in one extensive area of scattered/medium relief hardbottom (Figure 3). This hardbottom habitat has an average relief of over 30 cm. Percent coverage of hardbottom features in this area was over 20 percent living resources.

3.2.2 Borrow Area E

Area E could provide over 1MCY of material for potential placement along Indian Rocks Beach (Figure 4) (Dial Cordy 2001). Hardbottom resources within the pipeline corridor for Area E are limited to 10.2 acres of patchy/low relief hardbottom. Diver characterization of these resources revealed an average relief of less than 10 cm and an average coverage by living resources of less than 10 percent.

3.2.3 Borrow Area F

The pipeline corridor leading from Borrow Area F contains 18.2 acres of marine livebottom resources. These resources consist of 15.2 acres of patchy low relief hardbottom and an additional 3.1 acres of penshell/shellhash community. These hardbottom resources had an average of 33 percent cover and a relief of 27 cm with a mean relief over the entire area of 12.2 cm.

3.2.4 Borrow Area G

Borrow Area G has over 1.5 MCY of material available for placement along Pinellas County's beaches (Dial Cordy 2001). This material is situated over 1,100 acres of seafloor approximately 1.8 nm offshore of the area just south of Indian Rocks Beach, FL (Figure 1).

3.2.4.1 North Corridor

The northern corridor leading from Borrow Area G contains areas of scattered/medium relief hardbottom (Figure 5). These areas of scattered hardbottom total 7.9 acres and occur in the center of the pipeline corridor. This medium relief (Ñ=20 cm) hardbottom has an average percent cover of 33.3 percent. The most dominant living resource features covering the limestone in these areas were macroalgae and sponges (19.2 percent and 0.1 percent, respectively). Four percent of the living bottom surveyed along the transects surveyed were covered in gorgonian species.

3.2.4.2 South Corridor

The southern pipeline corridor leading from Borrow Area G has extensive hardbottom features (Figure 6). In total there are 50.1 acres of scattered/medium relief hardbottom and 0.6 acres of patchy/medium relief hardbottom within the survey limits of this pipeline corridor. The average percent cover of these hardbottom features was 35.5 percent with an average relief of 23.6 cm. Hardbottom features in this area consisted of medium relief limestone ledges and outcrops. Gorgonian species were one of the dominant features covering these rock features and accounted for 16.4 percent of the living cover.

3.2.5 Borrow Area H

Borrow Area H is the southernmost offshore borrow area surveyed and contains approximately 2.7 MCY material that could be placed on Pinellas County's beaches. Borrow Area H is 2.8 nautical miles offshore of the Treasure Island area (Dial Cordy 2001). Three pipeline corridors were surveyed, a northern corridor that terminates in the staging area located offshore of Florida Department of Environmental Protection (FDEP) Monuments R-99 to R-103, a central corridor that terminates on the beach just north of Johns Pass, and a southern corridor that would allow sand to be placed south of the Johns Pass area (Figures 1, 6, and 7).

3.2.5.1 North Corridor

The northern pipeline corridor leading from Borrow Area H has very little hardbottom resources located within the extents of the survey area. Only 2.7 acres of hardbottom resources were located during this survey. These are two small areas of patchy/medium relief hardbottom located near the nearshore end of the corridor (Figure 6).

3.2.5.2 Center Corridor

The central pipeline corridor for Borrow Area H contains one small area of hardbottom. This area of patchy/medium relief hardbottom covers 0.4 acres of seafloor. No other hardbottom resources exist in this pipeline corridor (Figure 7).

3.2.5.3 South Corridor

The longest pipeline corridor surveyed was the southern corridor leading from Borrow Area H. This corridor was just over 4 nautical miles in length. Located within this survey area was 5.5 acres of scattered/medium relief hardbottom. This area has a 41 percent living resource cover and a relief of approximately 50 cm. Sponges were the most dominant resource cover type in these hardbottom areas and results of the image analysis reveal that 16.4 percent was covered with sponge growth, while in this same area, macroalgae accounted for 12.7 percent and gorgonians 1.8 percent of the coverage.

3.2.6 Borrow Area I

Borrow Area I is the northern most and smallest of the offshore borrow areas. One pipeline corridor was investigated for Borrow Area I and would allow material to come ashore in the area south of Clearwater Pass (Figures 1 and 8).

Located within the pipeline corridor for Area I is an extensive area of scattered/low relief hardbottom. This area of hardbottom covers over 27.8 acres and extends the entire width of the surveyed corridor. Additionally, there are 20 acres of penshell/shellhash community along the eastern portion of this pipeline corridor. Point count analysis and diver characterizations show that this area of low relief hardbottom covers approximately 50 percent of the bottom where it occurs and has a relief of 23 cm. Sponges (32.1 percent), macroalgae (10.4 percent), gorgonians (3.8 percent, and corals (2.8 percent) are the cover types that typify these hardbottom areas.

3.3 Nearshore Staging Areas

Since the methods that dredging contractors will use to move the sand from the offshore borrow areas to the beach to be nourished is not known (i.e. hopper dredge, cutterhead dredge etc.) nearshore staging areas for dredge equipment were also surveyed for potential use. In total, six nearshore staging areas were surveyed and a summary of marine resources located in each area is discussed in this section.

3.3.1 Borrow Area D North (R-62 to R-63)

The staging area for the pipeline corridor Borrow Area D north is located offshore of FDEP Monuments R-62 to R-63. This staging area and nearshore corridor is predominately sand bottom with a few areas of penshell/shellhash communities. In total, 4.3 acres of penshell/shellhash community exists within this area (Figure 2). These communities, while not true hardbottom, do support a variety of marine life. In particular, it is an important community for the stone crab, which was documented extensively in these areas during the diver characterization.

3.3.2 Borrow Area D South (R-74 to R-78)

Located offshore between monuments R-74 to R-78 is the staging area surveyed for the pipeline corridor leading from the southern end of Borrow Area D (Figure 3). This staging area and nearshore corridor contains a permitted Pinellas County artificial reef site. The location of this artificial reef is shown on Figure 3. During the survey, debris from this artificial reef site was located north of the buoys marking the limits of the artificial reef. These areas where debris was located are shown on Figure 3 immediately north of the area defined as the reef site. There are 2.7 acres of patchy/medium relief hardbottom located in the southwestern corner of this staging area. Additionally, there are 32.9 acres of penshell/shellhash community located nearshore.

3.3.3 Borrow Areas E and F (R-84 to R-86)

The staging area surveyed between monuments R-84 to R-86 contains only 1.9 acres of patchy/low relief hardbottom. The majority of this resource is located in an isolated patch of hardbottom along the southeastern corner of the staging area (Figure 4).

3.3.4 Borrow Area G North (R- 91to R-93)

The northern pipeline corridor for Borrow Area G ends at the staging area offshore of Monuments R-91 to R-93. This staging area has a total of 12.5 acres of marine resources.

Figure 5 shows the relative distribution of patchy/low relief hardbottom located within this area. In total, there are 9.9 acres of patchy/low relief hardbottom in this area. The remaining 2.6 acres located in this area are along the southeastern boundary of the survey area and consists of penshell/shellhash community.

3.3.5 Borrow Area G South and H (R-99 to R-103)

Resources within this staging area are isolated patches randomly scattered throughout the area. In total, 8.2 acres of patchy/medium relief hardbottom are located within this area. These resources are distributed over the majority of the staging area (Figure 6). The largest areas of occurrence are along the northern edge of the staging area.

3.3.6 Borrow Area I (R-58 to R-61)

The staging area for Borrow Area I has a total area of 129.6 acres. This area is predominately sand (99.4 acres) and penshell/shellhash community (27.0 acres). Located in this staging area are also 3.2 acres of patchy/low relief hardbottom resources (Figure 7).

3.4 Pass-a-Grille Channel

The Pass-a-Grille Channel was also surveyed and characterized during this study. A total of 4.6 acres of marine resources were located within the survey limits of Pass-a-Grille Channel (Figure 9). These areas consisted of patchy/low relief hardbottom/livebottom within the interior portions of the channel.

4.0 CONCLUSIONS AND RECOMMENDATIONS

This survey was conducted to determine the potential for utilization of the pipeline corridors and nearshore areas located offshore of the Pinellas County shoreline. Since the methods to be employed by the contractors are not known a complete impact assessment cannot be fully reviewed at this time. Recommendations on the use of these areas and their potential for utilization in the future will be addressed in this section.

4.1 Pipeline Corridors

Utilization of pipeline corridors by dredging contractors may result in impacts to marine resources. The corridors for Borrow Areas D and G have particularly extensive areas of hardbottom resources (Table 8). These resources would not be avoidable should they be used for pipeline access to the beach. Both of these areas have nearshore staging areas that may be utilized and if it is cost effective, hopper dredging or some other technique may be utilized to minimize impacts. Should impacts be unavoidable, mitigation for these impacts would be required. Construction of artificial reefs may be attempted to offset the damage done by pipe placement.

The other pipeline corridors surveyed have few or isolated areas of hardbottom/livebottom habitats, and avoidance of these habitats may be possible. The corridors surveyed were 500 feet in width and the majority of pipeline corridors will only need to be approximately 50 feet in width. Careful planning and placement by the contractor can be used to avoid or minimize impacts to these resources.

Further surveying of the pipeline placement during construction, as well as equipment placement may need to be conducted before, during and after construction to judge actual impacts to the marine resources present in each area. This monitoring of the construction activity will allow for correct mitigation ratios and impact assessments.

4.2 Nearshore Staging Areas

The use of hopper dredges or booster pumps may require the utilization of the nearshore staging areas. Portions of these areas have marine resources as described above and summarized in Table 8. In most cases, however, these areas may be utilized with minimal impact to hardbottom/livebottom resources. Exclusion zones can be created in areas where marine resources are present, and access by the contractors machinery can be denied in these areas. Additionally, placement of pipelines can be done to avoid these nearshore habitats. Should any impacts be unavoidable within these nearshore areas mitigation would be required.

The staging area located at the southern end of Borrow Area D contains an artificial reef, which should be avoided. Buffer zones would need to be established to avoid this area. This survey revealed an area of debris north of this artificial reef. Storm events may be moving areas of this artificial reef from its original location. Examination of the side scan record and further surveying in the area prior to construction may be needed to insure a clear corridor for equipment prior to use.

The penshell/shellhash communities present within some of these nearshore staging areas are not true hardbottom. They do, however, appear to be an important marine resource within this area. Impacts to these areas should be included in any impacts analysis done for future projects. Consultation with the appropriate agencies for these habitats may also need to be done prior to any construction.

Monitoring of the areas to be utilized during a project should be done before, during and after construction. Monitoring of these habitats will not only allow better impact assessment but also aid in mitigation of these impacts and allow for better planning for future projects.

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DOMINICA REEF FISH STATUS 2002:
An Assessment of the Abundance and Species Composition of Dominican Reef Fishes.

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An Assessment of the Abundance and Species Composition of Dominican Reef Fishes

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Keywords Reef fishes, Dominica, species abundance, roving diver technique

Abstract Reef fishes were surveyed at eight sites along the western coast of Dominica using a combination of two different roving diver techniques. The purpose of the study was to establish a list of marine fish species found in Dominican waters as well as to rank those species according to abundance. The top five species most abundant species, from highest to lowest, were Brown Chromis (*Chromis multilineata*), Bicolor Damselfish (*Pomacentrus partitus*), Ocean Surgeonfish (*Acanthurus bahianus*), Sergeant Major (*Abudefduf saxatilis*), and Yellow Goatfish (*Mulloidichthys martinicus*). The top five most abundant families, from highest to lowest, were Pomacentridae, Acanthuridae, Mullidae, Haemulidae, and Aulostomidae. Species richness was also estimated at each of the eight survey sites.

Introduction

Reef fishes, as predators or grazers, play an important role in the community dynamics of coral reefs through their interactions with corals, algae, and other herbivores (AGRRA 1999). Fluctuations in fish populations, especially certain indicator species and guilds cause both direct and indirect shifts in the structures of fish communities as well as other components of coral communities (Hughes 1994). Disruption in the balance of reef fish assemblages can also decrease coral cover and increase algal abundances (Roberts 1995). Because of this importance, fishes are often a focus of monitoring and management programs to evaluate the condition of reef communities (Hatcher *et al.* 1989). The purpose of this study was to establish some baseline data on the abundance and species richness of reef fishes along the west coast of Dominica, a relatively young volcanic island in the Lesser Antilles chain. Dominica's underwater topography is characterized by a narrow, rocky, steeply sloping shelf upon which a variety of coral assemblages, and some true reef formations, are found. These coral communities attract a variety of fish species that are a mainstay of the local diet and economy. Thus, baseline data on Dominica's reef fish populations can be useful for fisheries management decisions as well as future scientific studies.

Materials and Methods

Fish surveys were conducted at eight study sites along the west coast of Dominica during the months of October and November 2002. Listing from the northernmost to the southernmost, these sites were Tabby Bay, Salisbury West, Salisbury East, Macoucherie, Tarou Point, Canefield, Champagne, and Scott's Head. Descriptions of each site can be found in the introduction of Smith *et al* (2002). A total of ten one-hour-long surveys were completed using both SCUBA and snorkeling equipment, with SCUBA being used at Salisbury East and Macoucherie and snorkeling at all others. Champagne and Macoucherie were both surveyed twice, while all other sites were only surveyed once. Surveys were carried out by utilizing two different roving diver techniques that were conducted simultaneously during each hour-long survey. The use of these two techniques resulted in two distinct measures of species abundance: timed scoring and visual scoring. During the surveys, species with visibly different life stages, such as some parrotfishes, wrasses, and angelifishes, were separated according to those stages. In addition, a separate

"species only" list was compiled in order to begin to establish a complete species list of Dominican reef fishes. This list was independent of the abundance data being taken and included any and all marine fish species that I was able identify in Dominican waters since September 2002. All fishes, with respect to both abundance and species only data, were identified *in situ* based upon Humann and Deloach (2002). Only those fishes that could be positively identified were included in the results.

Timed Scoring

Timed scoring was based upon the Random Swim Technique outlined in Rogers *et al* (1994). Roving surveys of reef fish were conducted for periods of 60 minutes at a time. Estimates of species abundance were determined based upon when in the survey each species was sighted, the theory being that the most abundant species would be seen sooner in the survey. Thus, the 60-minute surveys were split up into 10-minute periods. Species identified in each survey were then given a score between 0 and 6 based on what 10-minute period they were sighted in, with 6 being those sighted in the first 10 minutes and 1 being those in the last. Zero scores were given to fish that had been sighted in previous surveys but were not sighted in the specific survey being conducted. Thus, the timed scoring was as follows:

6 = seen within the first 10 minutes of the survey.
5 = seen between 11 and 20 minutes into the survey.
4 = seen between 21 and 30 minutes into the survey.
3 = seen between 31 and 40 minutes into the survey.
2 = seen between 41 and 50 minutes into the survey.
1 = seen between 51 and 60 minutes into the survey.
0 = not seen on that specific survey.

A mean timed score and its standard deviation was obtained for each species by averaging the scores of that species from all ten surveys. A sighting frequency (%) was obtained for each species by taking the number of surveys in which that species was sighted and dividing it by the total number of surveys.

Visual Scoring

In addition to the timed scoring system mentioned above, species abundance was also estimated using a visual scoring system. The visual scoring system is based upon the Roving Diver Technique (Schmitt and Sullivan 1996) used by the Reef Environmental Education Foundation (www.reef.org). Visual scores were determined using the same roving surveys mentioned before, but visual abundance estimates were independent of the 10-minute time intervals. Directly after each survey, while the species that had just been seen were still relatively fresh in mind, each species was assigned a visual abundance score between 0 and 4 based on how many of each species were seen during the whole of the one-hour survey. The logarithmic-based categories of the visual scoring system were as follows:

4 = Abundant = >100 individuals seen
3 = Many = Between 11 and 100 individuals seen
2 = Few = Between 2 and 10 individuals seen
1 = Single = Only one individual seen
0 = None = No individuals of this species were seen during that survey.

A mean visual score and its standard deviation was obtained for each species by averaging the scores of that species from all ten surveys. A sighting frequency (%) was obtained for each species by taking the number of surveys in which that species was sighted and dividing it by the total number of surveys.

Data Analysis

All survey data was input into Microsoft Excel spreadsheets for data analysis. In order to establish a rank-order list of species abundance, each species needed to be assigned an abundance score. Two different formulas were used to do this. One abundance score was the raw total score. This score was the sum of the timed scoring mean and visual scoring mean for each species. This total score was on a 10-point scale, six points for timed scoring and four points

for visual scoring, with a score of 10 being the highest abundance and a score of 0 being the lowest. A second abundance score took into account the sighting frequencies as well. In this case, the mean of each species, both timed and visual, was multiplied by that species' sighting frequency. Thus, each species received two "Mean*SF" scores, one for timed and one for visual. These two scores were added together to obtain a total abundance score that was on a 10-point scale, with 10 being the highest and 0 the lowest. Since this second scoring system took into account sighting frequencies as well, it resulted in a better delineation among species than did the raw total score. Thus, the only way a species could receive a perfect 10 in total abundance was if it appeared in every survey and received maximum timed and visual scores of 6 and 4 respectively in each one. This total abundance score was used to make a list of Dominican reef fishes that were ranked from greatest abundance to least. In order to rank abundance data on the various families, both the mean and max of all samples from each family was taken. Thus, the families could be ranked in four different ways: Raw Mean Total, Raw Max Total, Mean Total Abundance, and Max Total Abundance. Ranking differences between mean and max totals was based on the number of samples in each family. However, it appeared that the Max Total Abundance ranking best reflected the actual conditions (pers. obs.). Finally, the total number of species sighted during each survey was added to get an estimate of species richness from each site.

Results

Tables presenting all the data and abundance rankings are at the end of this document. The species only list included 115 fish species comprising 46 different families. Of the fishes on which abundance data was obtained, there were 87 different species comprising 35 families and 59 genuses. The top five species according to total abundance score, ranging from highest to lowest, were Brown Chromis, Bicolor Damselfish, Ocean Surgeonfish, Sergeant Major, and Yellow Goatfish. The top five families, from highest to lowest, according to max total abundance scoring were Pomacentridae, Acanthuridae, Mullidae, Haemulidae, and Aulostomidae. Species richness, according to the number of species sighted during each survey, was found to be highest at Champagne and lowest at Tabby Bay.

Discussion

The results presented in this paper are only intended to serve as a general baseline of data on Dominican reef fish populations. The species list presented represents many of the most commonly sighted fish species but should not be considered comprehensive as more surveys and different survey techniques might reveal even more species. This study was limited by the fact that only one person was conducting the surveys. Future studies could be improved through a combination of more surveys and multiple surveyors. While the abundance data does seem to provide a good picture of the actual populations (pers. obs.), it is important to note that the roving diver techniques used in this study have known advantages and disadvantages when compared to other survey techniques such as belt transects. Random swim/roving diver techniques are more likely to record rare and cryptic species, and thus provide a more complete species list, than belt transects. However, random swim/roving diver techniques cannot be used in density estimates since the surveys are conducted over a large area of undetermined size. Furthermore, these types of surveys provide less quantitative data by not including size and numbers of individuals, which could be used in determining biomass (Rogers *et al.* 1994; Schmitt *et al.* 2002). Schmitt *et al.* (2002) have shown that a combination of belt transect and roving diver techniques provides a more complete overall species assessment of reef fishes than does either method in isolation as a result of specific biases and limitations inherent to each individual method. Thus, the data presented here could be used as a starting point for conducting future studies that employ both methods.

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CRAMP Rapid Assessment. Fish Survey Techniques

Fish populations are highly variable, requiring numerous transects to quantify absolute values of fish communities. Spatial and temporal variability can reduce statistical power by increasing standard deviations. The rapid assessment technique (RAT) was designed to use quantitative, relative values to compare stations and sites relative to others. This can be calculated within a site, by island or statewide. In this manner, RATs can cover a large spatial region and keep costs and effort at a minimum, while maintaining statistical integrity by developing a large sample size. In addition, its design allows for statistical comparability with the more intensive, repeatable Long-term monitoring transects.

To encompass as wide a spatial range as possible and to address the issue of spatial variability, a many but small sampling strategy was adopted (McCune and Lesica, 1992). The RAT is a trade-off between size and number of sampling units. This technique provides an efficient sampling design to assess extremely large areas. There are many advantages to selecting many, short transects over fewer transects of longer length (McCune and Grace, 2001).

- Cover of common species is more accurately and precisely estimated.
- Larger coverage of sites increases environmental representation.
- Smaller sampling units reduce bias against cryptic species by forcing visual contact to specific spots, avoiding selective species detection.
- Reduces overestimation of rare species.
- Sampling effort and efficiency are not compromised.

Fish populations are quantified using standard visual belt transects (Brock 1954). Transect location is determined using pre-selected random

points. SCUBA divers swim along one 25 m x 5 m transect (125 m2) at each station recording species, quantity and total fish length. All fishes are identified to the lowest taxon possible.

Kuulei Rodgers recording fish numbers and lengths on rapid assessment at Waikīkī in February 2002. Photo by Erica Muse.

Total length is estimated to the nearest cm in the field and converted to biomass estimates (tons/hectare) using length-weight fitting parameters. In order to estimate fish biomass from underwater length observations, most fitting parameters were obtained from the Hawai‘i Cooperative Fishery Research Unit (HCFRU). Additionally, locally unavailable fitting parameters were obtained from **Fishbase** whose length-weight relationship is derived from over 1,000 references. Congeners of similar shape within certain genera were used in those rare cases lacking information.

Conversions between recorded total length (TL) and other length types (e.g. fork length FL) contained in databases involved the use of linear regressions and ratios from Fishbase linking length types. A predictive

linear regression of logM vs. logL was used in most cases to estimate the fitting parameters of the length-weight relationship. Visual length estimates were converted to weight using the formula $M = a * L^b$ where M=mass in grams, L=standard length in mm and a and b are fitting parameters.

Any anomalous values were detected by calculating a rough estimate for a given body type. The general trend for a 10 cm fish of the common fusiform shape should be approximately 10 g. Gross deviations were replaced with values from the alternate source.

Trophic levels for fish species were determined using published Fishbase data. The trophic categories included: piscivores, herbivores, detritivores, mobile and sessile invertebrate feeders, and zooplanktivores.

To minimize observer variability, only two divers were used in fish assessments. Calibration of the divers was conducted at Kahe Point, O‘ahu (four transects) and Puhi Bay, Hawai‘i (eight transects). No significant differences were found between the two divers for estimates of number or length of fishes.

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Calypso LNG Deepwater Port Project, Florida
Marine Benthic Video Survey

FINAL REPORT

12 June 2006

Submitted to:

Ecology and Environment, Inc. & SUEZ Energy North America, Inc.

Submitted by:

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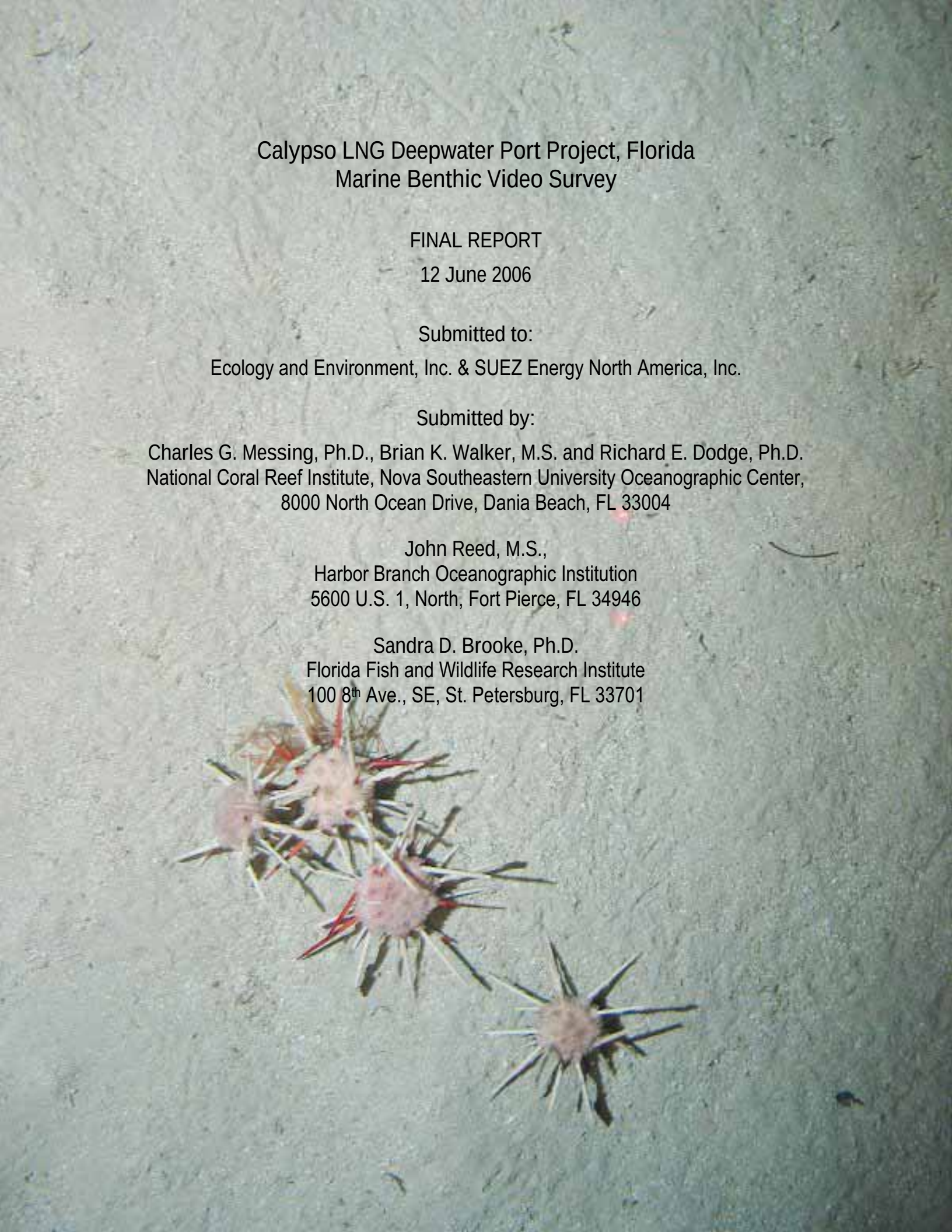

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Table 8. Counts and densities of individual sessile and semisessile organisms in CPC analysis images.

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III. EXECUTIVE SUMMARY

- The benthic video survey carried out for the *Calypso* Liquefied Natural Gas Deep Water Port Project (LNG DWP) examined ~52 nm of linear transects of the seafloor off Fort Lauderdale, FL, in and to the north of the geohazards survey area using the US Navy's Television Observed Nautical Grappling System (TONGS) remotely operated vehicle (ROV) conducted from 15 to 18 April 2006.

- Analyses of videographic and still photographic data revealed six habitat types:
  1) Sediment (obsolete rippled and flat bioturbated),
  2) Large-scale sediment features – large depressions and sand waves.
  3) Tilefish burrows – one great northern tilefish (*Lopholatilus chamaeleonticeps*), and a few burrows of probable blueline tilefish (*Caulolatilus microps*).
  4) Pennatulids – chiefly widely scattered colonies of a sea pen in >900 ft.
  2) Low-cover hard bottom – scattered clusters of rubble or small rocks, often in patches a few meters across, rarely in more extensive fields, and separated by expanses of sediment, occasionally accompanied by a few low-relief rocks up to 0.8 m across and rare veneered slabs or pavements to 1 m across.
  3) High-cover hard bottom – low- to moderate-relief characterized by phosphoritic limestone outcrops, pavement and slabs, each chiefly <2 m across, with varying amounts of rubble and small to large rocks, frequently in patches separated by expanses of sediment and intermixed with low-cover hard-bottom areas.

- The most abundant organisms on hard bottoms were a variety of sea anemones (Actiniaria), nephtheid soft corals (?*Capnella nigra*), zoanthids (colonial anemones) and echiuran spoon worms, accompanied by smaller numbers of primnoid and isidid octocorals, stylasterid lace corals, demosponges and hexactinellid glass sponges. The only stony corals observed were small solitary azooxanthellate cup corals (=2 cm) (except for two small branching colonies on the fuselage of a sunken airplane).The most common fish in this habitat was the blacktail codling, *Laemonema melanurum* (Moridae). Four large fishes (grouper or snapper) were seen in side cameras.

- A total of 869 still images were analyzed in eight still photographic series identified as having high biological interest (based on organism abundance and diversity, and extent of exposed hard substrate), ranging from 82 to 136 per series with a mean of 108.6 images per series. Coral Point Count (CPC)© software was used to code 50 points in each image. Hard substrates accounted for 17.10 to 95.32% of cover in these eight selected predominantly hard bottom areas. Percent coverage by all organisms combined (mobile and sessile) ranged from 1.01 to 9.00%.

- We also counted all organisms larger than 3-4 cm in the same image set. Area covered ranged from 52.12 to 182.04 m^2 per site. Total organism densities ranged from 3.85 to 10.80 m^{-2}, with sessile and semi-sessile habitat-forming groups (sponges and cnidarians) ranging from 3.15 to 6.49 m^{-2}. Sea anemones were the most abundant organisms at 5 of 8 sites, with zoanthids and echiurans most abundant in the other three. *Capnella nigra* ranked second through fourth. Maximum densities of dominant groups were echiurans (3.32 m^{-2}), zoanthids (2.86 m^{-2}), sea anemones (1.90 m^{-2}), nephtheids (1.22 m^{-2}), and total sponges (0.71 m^{-2}). No other group occurred at densities greater than 0.5 m^{-2}. Organisms treated as corals contributed at most 0.48 (gorgonians) and 0.45 colonies m^{-2} (stylasterids), both at site 8.

IV. INTRODUCTION

Calypso LNG, LLC, a subsidiary of SUEZ Energy North America, Inc., proposes to submit a Deepwater Port (DWP) application for a proposed offshore liquefied natural gas (LNG) import Deepwater Port terminal located approximately 10 miles northeast of Port Everglades, Broward County, Florida. This facility, the first LNG DWP proposed for construction within the exclusive economic zone (EEZ) off the southeastern Florida coast, would connect with a previously permitted submarine pipeline (the *Calypso Pipeline*) to transport regasified LNG from the DWP to the Florida Gas Transmission Pipeline. The DWP licensing process requires identification and characterization of benthic marine resources that may be impacted by project activities. Dodge et al. (2001) and Messing et al. (2003) carried out field biological surveys using scuba and remotely operated vehicles (ROVs) to identify bottom characteristics and benthic macrofaunal assemblages and habitats along the previously permitted *Calypso Pipeline* route from the shoreline to a depth of 183 m (600 ft). These surveys were conducted using methods consistent with the Florida Department of Environmental Protection Office of Intergovernmental Program's 2002 guidelines for offshore surveys of linear features (DEP 2002) and included both qualitative videographic and quantitative still photographic analyses. This report documents the results of the survey carried out by Nova Southeastern University to characterize the benthic habitats and resources of the area proposed for the Calypso DWP construction. This survey consists of 52 nm of videographic and quantitative still photographic transects within and adjacent to the proposed construction area—a parallelogram 7.4 nm by 7.0 nm between ~210 and 300 m depth (689-984 FSW).

A detailed geohazards survey carried out by INTEC Engineering Partnership, LTD, in March 2006 characterized the seafloor and shallow sub-seafloor geology of the study area using high-resolution multi-beam bathymetry, high-resolution sidescan sonar imagery, sub-bottom profiles and magnetometer data. Line spacing was based on 125% high-resolution bathymetry data and 200% sidescan sonar coverage. The resulting map depicted apparent variations in seafloor substrates, i.e., between hard bottoms and unconsolidated sediments, and provided the basis for designing the pattern of the benthic video and still photographic survey, which provided ground-truthing for the geohazards survey.

V. PURPOSE

The purpose of the benthic video survey is to locate, characterize, and determine the distribution of benthic marine communities in the area encompassed by the geohazards survey. Along with the geohazards survey, the benthic video survey will be used to determine a preferred location for the LNG DWP, and within that location to ascertain the best anchor and chain locations for avoiding or minimizing impacts to sensitive benthic habitats. Locations of suction anchors and chain lines are not yet known. This qualitative video and quantitative digital still photographic survey thus will locate, characterize, and determine the areas of benthic communities that may be vulnerable to impact from the proposed *Calypso* DWP Project. The results will be incorporated into a DWP application to be prepared for agency submission.

VI. STUDY AREA

A. Physical Environment

The southeastern Florida continental shelf is part of an extensive subsiding carbonate platform that includes the Florida peninsula and west Florida shelf. The survey area lies at the northern end of the Miami Terrace, a 120-km-long elongated outcrop of partially buried phosphoritic mid-Tertiary limestone that

extends along southeastern Florida from Key Largo to Boca Raton at depths of ~200-400 m (Figure 1). Previous work along the proposed *Calypso Pipeline* route to the west of the study area revealed chiefly sediment substrates with areas of scattered limestone rubble and larger low-relief rocks (Messing et al. 2003). In 1970, Ballard and Uchupi (1971) traversed a portion of the study area using the submersible *Ben Franklin* (red line in Figure 1B). Within proposed DWP site depths, they reported a thin veneer of rippled sand grading first into an area of phosphoritic nodules in a carbonate sand matrix and then, with increasing depth to the east (below ~300 m), massive phosphoritic outcrops. The eastward terrace margin, which is best developed south-southeast of the study area, consists of slabs, pavements, ridges and scarps with up to ~90-m vertical relief (Kofoed & Malloy 1965, Uchupi 1966 1969, Uchupi & Emery 1967, Malloy & Hurley 1970, Neumann & Ball 1970). The study area lies under the Gulf Stream, or Florida Current, which flows northerly at speeds of 3 knots or greater, while the bottom current often reverses and may flow southerly at up to 1 knot.

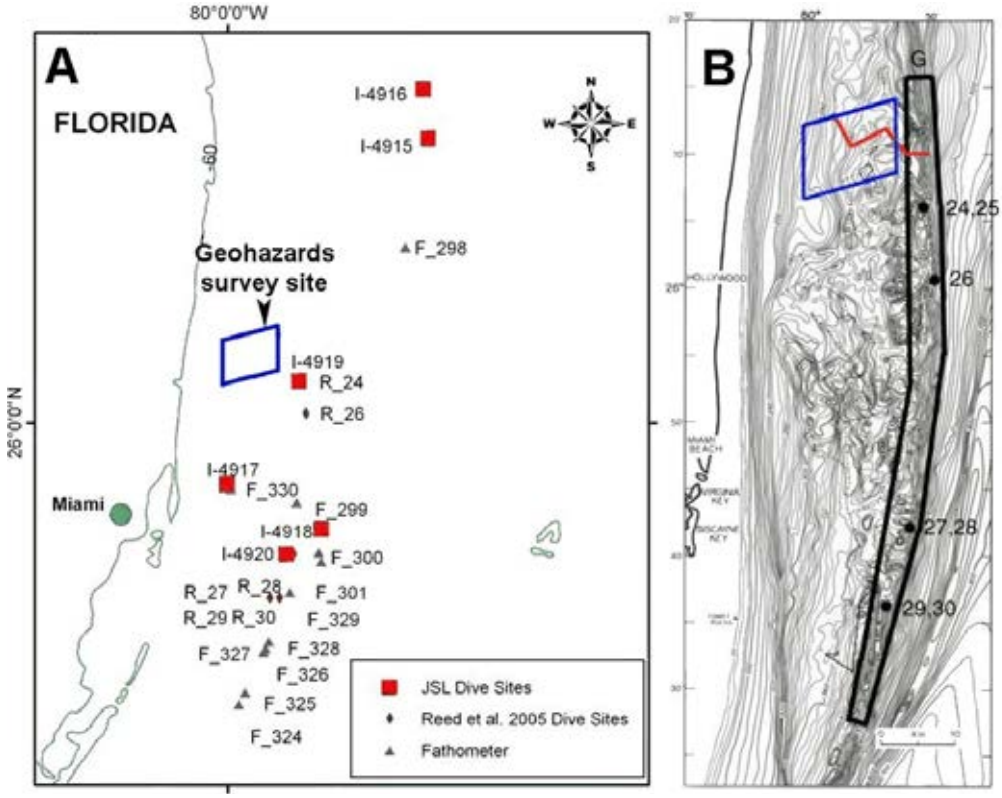

Figure 1. A. Location of geohazards survey site relative to submersible dives and fathometer transects completed by John Reed and others (Harbor Branch Oceanographic Institution, Ft. Pierce, FL). B. Map of the Miami Terrace (Malloy and Hurley 1970) with the steep Miami Escarpment outlined in black and the geohazards survey area in blue. Red line indicates track of *Ben Franklin* (Ballard and Uchupi 1971). Numbered dots are Reed et al. (2006) submersible sites.

B. Biological Environment

No prior detailed biological survey has taken place within the proposed DWP site. Ballard and Uchupi (1971) show two indistinct photographs of apparently barren phosphorite and sediment substrates (one with a wreckfish, *Polyprion americanus*). However, more recent submersible dives to the east and southeast of the proposed site along the upper Miami Terrace escarpment (Figure 1A) have observed rich benthic communities including sponges, octocorals and deep-water corals on exposed limestone

substrates (C. Messing personal observations, Reed et al. 2006). The benthic macrofaunal assemblage on sediment substrates to the west of the study area is dominated by the sea star *Coronaster briareus*, cerianthid (burrowing) anemones, and decapod crustaceans (galatheids, *Cancer borealis*, *Bathynectes longispina*). Rubble and rock substrates may support hydroids, sabellid polychaetes, solitary corals and sea anemones. One anemone species (possibly *Actinauge longicornis*) typically occurs on small bits of rubble and in depressions on sediment where it anchors to a bolus of mud. Larger rocks are covered with a fine turf (possibly red algae or agglutinating foraminiferans) (Messing et al. 2003). One recent trawl collection within the depth range of the study area retrieved bamboo coral (Isididae) (C. Messing, personal observation).

VII. BACKGROUND INFORMATION

Geophysical and benthic video surveys of the permitted *Calypso Pipeline* route west of the proposed LNG DWP site area were conducted by RJ Brown and Nova Southeastern University under contract to Enron. The survey included sidescan sonar and magnetometer transects. A Geohazards Report was prepared by Mr. John Hoffman, Geoscience Earth & Marine Services (GEMS) for the route proposed by Enron.

The MMS (Gulf of Mexico OCS Region, NTL No. 99-G16) defines live-bottom areas as seagrass communities; those areas that contain biological assemblages consisting of sessile invertebrates living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography, and areas where the lithotope favors the accumulation of turtles, fishes, or other fauna. Discussion with MMS indicates that sessile invertebrate assemblages to be documented include those on sediment (e.g., sea pens) as well as on hard bottom at densities of ≥ 1 m^{-2} over areas of at least several square meters.

The South Atlantic Fisheries Management Council (SAFMC), refers to hard bottom as a class of coral communities occurring in temperate, subtropical, and tropical regions (SAFMC 1998a). These communities lack the diversity, density and reef-building capabilities of other classes of coral communities, and are the most widespread of coral communities within the South Atlantic Bight (SAFMC 1998) to the north of the survey area. Hard bottom ranges from relatively flat low-relief surfaces (<0.5 m vertical relief) to several meters in relief. Hard bottom is sometimes referred to as live bottom due to the amount of living organisms attached to or inside these hard substrates. Note that in this context, coral includes non-accreting taxa such as octocorals and antipatharians (black corals) as well as stony corals and other taxa with solid calcareous skeletons.

The Southeast Area Monitoring and Assessment Program (SEAMAP) deep-water mapping project of the South Atlantic Fishery Management Council (SAFMC) is in the process of documenting deep-water, hard-bottom habitat from existing data throughout the South Atlantic Bight and Strait of Florida (Arendt et al. 2003). The SEAMAP bottom mapping workgroup has defined deep-water hard bottom as including the following subcategories of habitat types: coral, rock rubble, coral rubble, exposed hard pavement, thinly covered hard substrate, and artificial structures. In addition, a “Special Habitats” category includes the subcategories of canyons, tilefish burrows, consolidated mud, methane seeps, sinkholes and coral banks. Although the SAFMC has not yet completed the deep-water coral component of SAFMC Fishery Ecosystem Plan, they define deep-water corals as including Scleractinia (stony corals), Octocorallia (gorgonians), Stylasteridae (lace corals), and Antipatharia (black corals). Table 1 lists deep-water colony-forming corals capable of forming complex 3-dimensional habitats in 200-2000 m off the southeastern United States (Blake Plateau to Strait of Florida). Table 2 lists additional sessile organisms that could

indicate hard-bottom substrates in the same region. Sponges (Phylum Porifera, Classes Demospongiae and Hexactinellida) are the primary non-cnidarian group that also may contribute substantially to the 3-dimensional complexity of deep-water hard-bottom communities.

Table 1. Deep-water colony-forming corals capable of forming complex 3-dimensional habitats in 200-2000 m off the southeastern United States (Blake Plateau to Strait of Florida). Common names are given in parentheses.

- Phylum Cnidaria
  - Subphylum Anthozoa
    - Class Octocorallia (soft corals, gorgonians, sea pens)
      - Order Alcyonacea 14 families
        - Family Coralliidae (precious corals)
        - Family Chrysogorgiidae (gold corals)
        - Family Isididae (bamboo corals)
        - Family Paragorgiidae (bubblegum corals)
        - Family Paramuriceidae
        - Family Plexauridae
        - Family Primnoidae
        - Family Ellisellidae
        - Family Gorgoniidae
    - Class Hexacorallia (stony corals, anemones, black corals)
      - Order Zoanthidea (colonial anemones)
        - Family Parazoanthidae (*Gerardia* sp.)
      - Order Antipatharia (black corals)
        - Family Antipathidae
        - Family Myriopathidae
        - Family Schizopathidae
        - Family Cladopathidae
        - Family Leiopathidae
      - Order Scleractinia (stony corals)
        - Family Oculinidae (*Madrepora oculata* & *M. carolinae*)
        - Family Caryophylliidae (*Lophelia pertusa*)
        - Family Dendrophylliidae (*Enallopsammia profunda*)
        - Family Pocilloporidae (*Madracis* spp.)
  - Subphylum Medusozoa
    - Class Hydrozoa
      - Order Filifera
        - Family Stylasteridae (lace corals)

Table 2. Sessile or semisessile organisms other than colonial corals that may indicate hard-bottom substrates in 200-2000 m off the southeastern United States (Blake Plateau to Strait of Florida).

- Phylum Porifera (sponges)
  - Class Hexactinellida (glass sponges)
    - Order Amphidiscosida
    - Order Lyssacinosida
    - Order Lychiniscosida
    - Order Hexactinosida
  - Class Demospongiae
    - Order Astrophorida (5 families)
    - Order Spirophorida (1 family)

Order Lithistida (6 families)
Order Hadromerida (4 families)
Order Halichondrida (2 families)
Order Agelasida (1 family)
Order Axinellida (6 families)
Order Poecilosclerida (8 families)
Order Haplosclerida (5 families)
Order Dictyoceratida (2 families)
Order Dendroceratida (1 family)
Order Verongida (2 families)

Phylum Cnidaria
- Subphylum Medusozoa
  - Class Hydrozoa
    - Order Leptothecata (thecate hydroids)
- Subphylum Anthozoa
  - Class Octocorallia
    - Order Alcyonacea (soft corals)
      - Family Alcyoniidae
      - Family Nidaliidae
      - Family Nephtheidae
      - Family Anthothelidae
      - Family Spongiodermatidae
  - Class Hexacorallia
    - Order Scleractinia (solitary stony corals)
      - Family Caryophylliidae (e.g., *Paracyathus, Trochocyathus*)
      - Family Flabellidae (e.g., *Javania*)
      - Family Guyniidae (e.g., *Stenocyathus*)
      - Family Dendrophyliidae (e.g., *Balanophyllia, Bathypsammia*)
    - Order Zoanthidea (zoanthids, colonial anemones)
      - Several families
    - Order Actiniaria (sea anemones)
      - Numerous families in several orders

Sea pens (Order Pennatulacea) are colonial, often plume-like octocorals that, unlike most soft corals and gorgonians, typically anchor in unconsolidated sediments. However, like other octocorals, they are tall enough and may occur in great enough densities to generate complex 3-dimensional benthic habitat. They are included in the survey results.

The productivity of hard-bottom communities varies depending upon environmental and physical factors including but not limited to depth, current, light penetration, reef topography, habitat availability and location. Areas of hard-bottom provide cover and foraging areas for many fish and invertebrates, including several commercially important species. The importance of hard-bottom to fisheries stocks has been recognized, and the SAFMC has designated all natural and artificial hard-bottom as Essential Fish Habitat (EFH) and/or Habitat Area of Particular Concern (HAPC).

VIII. METHODS

A. Remotely Operated Vehicle (ROV)

The survey used the Television Observed Nautical Grappling System (TONGS), a deep-water heavy-lift underwater vehicle owned and operated by the Naval Surface Warfare Center, Carderock Division, South Florida Testing Facility (SFTF), Dania Beach, FL (Figure 2). TONGS has a 10,000-ft operating depth, 10,000-lb lift capability, and can operate in currents in excess of 5 kt within a 1-yd radius on the seafloor for prolonged periods. Underwater position is determined using an ultra-short baseline acoustic tracking system integrated into a differential global positioning system (DGPS), which provides highly-accurate (±1 yd) georeferenced bottom positions. TONGS is equipped with 4 color cameras, multiple underwater lights, dual-frequency imaging and search sonar, altimeter and depth sensor. Two cameras are mounted to a pan-and-tilt unit to provide variable camera orientation. TONGS also has two thrusters for orientation and minor positional changes (±30 ft). All control, data, and video are multiplexed thru a fiber-optic telemetry system to the surface, providing wide bandwidth and high-quality video (William Baxley, SFTF, personal communication). For this survey, TONGS was equipped with a Kongsberg OE-1373 high-resolution video camera, OE11242 Flashgun and OE14208 Digital stills camera, the latter provided with a pair of scaling lasers spaced 8 cm apart. The survey was carried out aboard the University of Miami's research vessel catamaran *F. G. Walton Smith* (length 96 ft, beam 40 ft, draft 5 ft 6 in, gross tonnage 97, speed 12 kt).

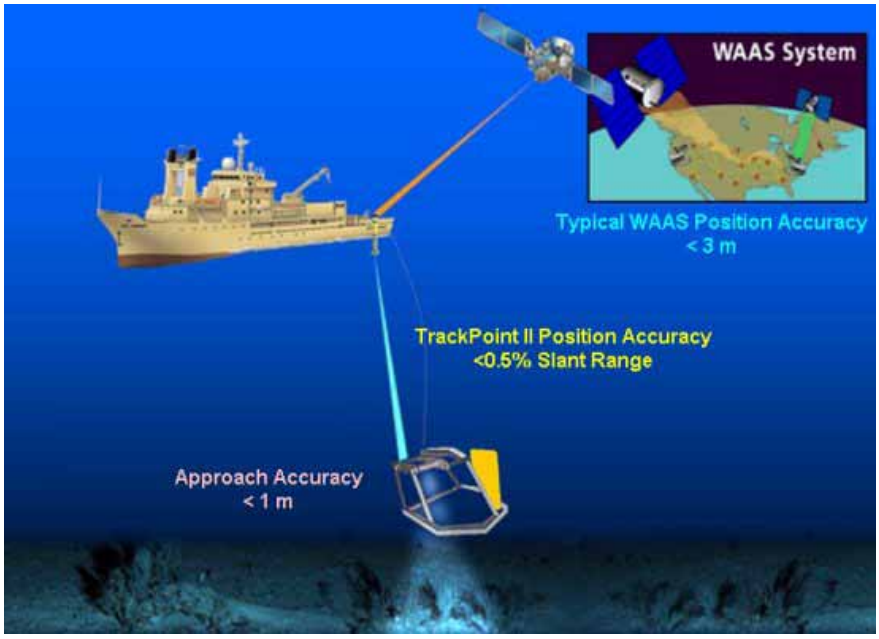

Figure 2. Television Observed Nautical Grappling System (TONGS).

B. Survey Pattern

The initially outlined transect pattern consisted of 5 major east-west survey lines ~7 nm long and ~1.5 nm apart in a proposed rectangular geohazards survey area. After the survey area was modified as a parallelogram, transects were oriented WSW-ENE and spaced as shown by Martin Morrison (INTEC Engineering) so that the 5-transect pattern would cover a larger area than strictly E-W lines and to transit as many of the apparent hard-bottom areas suggested by irregular topography in the geohazards sidescan

map. Transects were numbered 1 to 5 beginning with the southernmost. We submitted this pattern for agency comment. Following examination of the geohazards sidescan imagery, which revealed extensive apparent hard-bottom along the southernmost EW1 transect, and discussions with agency representatives, this transect (and EW Tie1) was replaced by an alternative E-W transect (Optional Northern BVS Transect in Figure 4; subsequently renamed EW6) ~1 nm north of and parallel to EW5, just outside of the geohazards survey area, because sidescan imagery suggested that most of the northern margin of the survey area was unconsolidated substrate. This was connected to EW5 by Tie EW5 at the northeastern corner of the geohazards survey area.

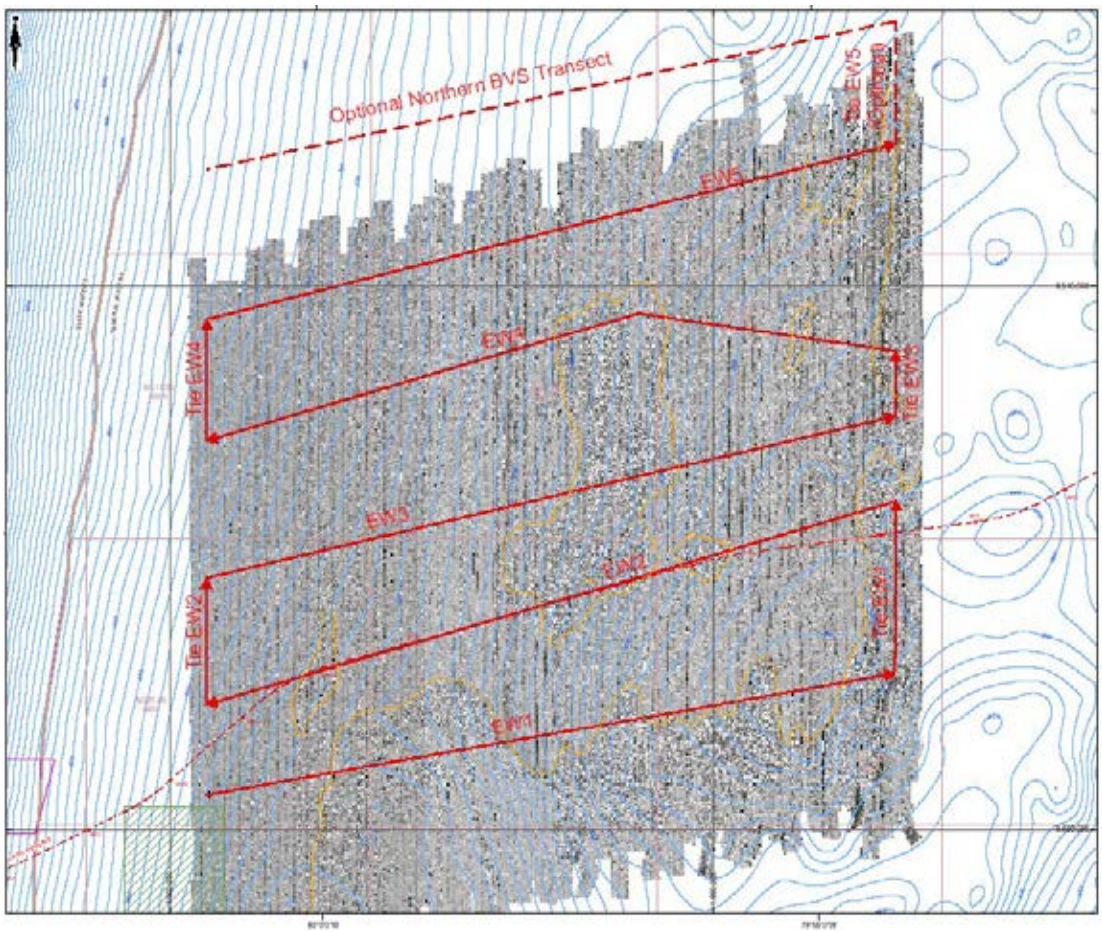

Figure 3. Planned transect pattern of 5 major E-W survey lines, each ~7.5 nm long, connected by shorter Tie lines.

Figure 4 shows the operational transect pattern as modified immediately before and added to during field operations. (It does not show the actual ROV path.) Transect EW2, which ran along the proposed *Calypso Pipeline* route for most of its length, was modified at its eastern and western ends to duplicate the entire proposed pipeline route within the geohazards survey area; this required a short southern extension to Transect Tie EW2 (green line in figure 4). During field operations, Tie EW5, between EW5 and EW6, was relocated ~a few hundred meters west of its original location in order to transit an area that preliminary sidescan imagery suggested might include a series of sinkholes or hard bottom. Subsequent analysis by INTEC has indicated that they are not sinkholes; they are treated here as large depressions. Also during field operations and with the agreement of Calypso LNG, LLC, a series of shorter interconnected transect lines were added to document the presence or absence of hard substrates north of the northeastern margin

of the geohazards survey area (blue lines in figure 4). Table 3 lists the transects in the sequence they were surveyed with the numbered videotapes recorded during each.

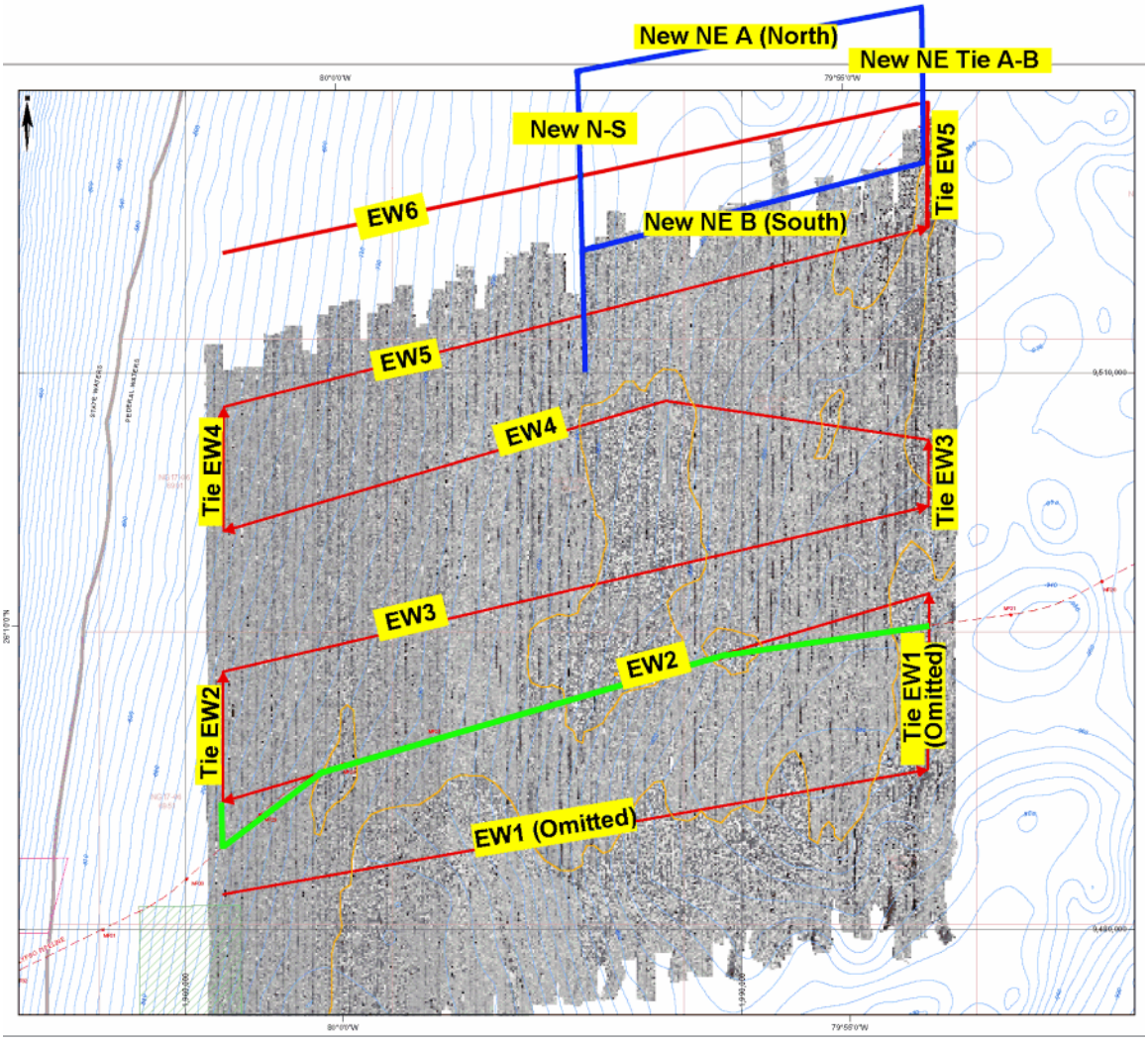

Figure 4. Operational transect pattern. Gray area represents seafloor topography based on a preliminary assessment of geohazards sidescan data. Orange contours outline areas of irregular topography initially interpreted as hard bottom. Transect EW2 was modified to duplicate the entire proposed pipeline route within the geohazards survey area (green line). Blue transect lines were added during field operations to document the presence or absence of hard substrates north of the northeastern margin of the geohazards survey area. Transects EW1 and Tie EW1 were omitted. Arrowheads indicate the planned survey direction; the actual survey was carried out in reverse (Table 3).

Table 3. Sequence in which transects were surveyed and tapes recorded. The eastern half of EW6 was repeated because the vessel drifted off course during the initial transit. See Figure 5 for survey pattern.

Sequence no.	Transect Name	Tapes recorded
1	EW6 (West half)	1-10
2	Tie EW5	11-13
3	EW5	14-19
4	Tie EW4	20-21
5	EW4	22-31(part)
6	Tie EW3	31(part)-32(part)
7	EW3	32(part)-41
8	Tie EW2	42-45
9	EW2	46-55
10	EW6 (East half)	56-59
11	New NE B (South)	60-63
12	New NE Tie A-B	64-66(part)
13	New NE A (North)	66(part)-69(part)
14	New N-S	69(part)-73

C. Data Collection

The survey was conducted pursuant to United States Department of the Interior Minerals Management Service (MMS) guidelines and regulations for assessment of impacts on marine resources and the Florida Fish and Wildlife Conservation Commission (FFWCC) "Guidelines for Conducting Offshore Benthic Surveys" as modified by discussions with MMS representative Gary Goeke. Proposed methods were outlined, adjusted and vetted by representatives of the following agencies during a meeting in West Palm Beach, FL, on 11 Apr 2006: U.S. Coast Guard, Army Corps of Engineers, Florida Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission, Minerals Management Service and NOAA Fisheries.

Video was run continuously throughout the survey while the ROV was on the bottom (i.e., within 1-2 m of the seafloor. Still images (1-2 MB each) were taken at ~10-min intervals over sediment substrates. Over areas of biological interest on hard substrates, still images were taken repeatedly as soon as the strobe recycled and the ROV moved far enough to avoid overlapping exposures. Images were also taken of specific organisms on all substrates for identification purposes. We selected 8 sites for quantitative plan-view digital photography on the basis of their greater relief and apparent biological complexity and diversity relative to surrounding substrates. We planned to use ~100 images per site with satisfactory exposures for quantitative analyses, each series beginning on a habitat of high biological interest. However, in three cases, somewhat fewer than 100 images proved usable (99 at site 3, 97 at site 4 and 82 at site 5). At the other five sites, we analyzed more than 100 images (103 to 136; see table 5 below) so that each series ended with exposures showing habitats of biological interest, rather than ending with a series on empty sediment.

D. Data Analyses

Following the surveys, video data were reviewed in the laboratory to confirm organism identifications as far as possible and to define biological zones and benthic habitats. Original field transcripts were summarized to produce habitat descriptions and identify transitions between habitats. Quantitative digital photographs were processed in the laboratory, e.g., to eliminate out-of-focus images and to improve image contrast when necessary. We used Coral Point Count (CPC)©, a proprietary software developed by the National Coral Reef Institute at the Nova Southeastern University Oceanographic Center. With this software, the user selects a rectangular region of each digital image of the sea floor for analysis. In this case, the selected area encompassed the full area of each photograph. The user then projects a series of random points onto the selected area of the image and identifies the organism or bottom type at each point according to a pre-selected list of categories (e.g., rubble, sediment-veneered hard bottom, unidentified sponge, Ceriantharia, Primnoidae, *Aphrocallistes* sp.) available to the user via an on-screen menu.

Because the CPC software was developed for use in shallow-water habitats with high densities of organisms, the relatively low densities of benthic hard-bottom macrofauna anticipated in this study would have required an excessive number of random points, probably at least 100 per image, in order to accurately capture the diversity of organisms and reflect their densities and percent cover. As a result, following discussions with and agreement by agency representatives, images were subjected to a two-stage analysis. Each image was initially analyzed using CPC software for percent substrate cover (e.g., hard-bottom, sediment-veneered hard-bottom, sediment) with organisms identified to general category (e.g., sponge, cnidarian, echinoderm) at a density of 50 points per image. Each image was then re-examined and all organisms larger than 3-4 cm enumerated and identified as specifically as possible (e.g., *Capnella* ?*nigra*, *Phakellia* sp., Isididae, anemone sp. 1, unidentified hexactinellid). Numbers of encrusting and small colonial organisms (e.g., hydroids, zoanthids) were approximated. Small organisms (<3-4 cm; e.g., ophiuroids, solitary corals, chitons) recognizable in still images were ranked by relative abundance classes (i.e., few, common, abundant) and were not included in quantitative analyses. Image area was calculated by converting image length and width in pixels to centimeters based on the number of pixels equivalent to the 8-cm laser scale. Organism densities per square meter (m^{-2}) were calculated by extrapolating from the number of organisms in the image area. From the combination of videographic and still photographic data, we mapped habitat data onto ROV transect tracklines with attributes containing habitat classifications, substrate characteristics and important biological features. Because ROV-based habitat data closely tracked the distribution of bottom types generated by the refined geohazards sidescan and geophysical data, we used these latter to interpolate the boundaries of hard bottom, unconsolidated sediment substrate and large-scale sedimentary features between transect lines. Although we recognized a distinction between low- and high-cover hard-bottom habitats, we mapped all hard-bottom areas between transect lines as a single “higher-cover hard-bottom” habitat (red areas in Figure 5) because the complex patchy mosaic of low- and high-cover could not be interpolated between transect lines. North of the geohazards survey area, where no geophysical data was available, we generated GIS habitat polygons from ROV-based data to approximate the distributions of major habitat types (hatched areas in Figure 5). After analysis of each image, the data were saved into an Excel database for analyses of 1) raw percent composition and 2) percent composition per area for each quantitative photo site. Calculations excluded all points categorized as photo effects (i.e., shadow, laser).

E. Terminology

Seafloor habitats, e.g., hard bottom, soft bottom and live bottom are defined above. In most scientific publications, measurements are reported in metric units. However, in this report, parameters are reported in the units in which they were originally recorded (English or metric). For example, Mile Post units provided

by INTEC Engineering are in statute miles and bathymetric charts give depth contours in feet. Distance over bottom was reported by the ROV and ship's crews in nautical miles. The depth readout overlay on the videotape is in feet, so that verbal and written indications of depth throughout field operations are in feet. However, vertical relief of bottom features, e.g., boulder, slab, was reported as low relief (<0.5 m) or moderate relief (0.5-1.0 m). No high-relief features (>1.0 m) were observed. These are relative terms and dependent on the size of features within an area. Estimates of size of benthic organisms and fishes are in centimeters, because the parallel scaling lasers on the ROV used by the observer to estimate size were 8 cm apart.

Conversion Table

1 meter = 3.28 feet	1 inch = 2.54 cm
1 statute mile = 5280 ft or 1609 m	1 nautical mile = 6076 ft or 1852 m
1 knot = 50 cm sec^{-1}	

F. Summary of Survey Protocols

1) An ROV equipped with high-quality video and still cameras surveyed a series of transect lines within and adjacent to the geohazards survey area totaling ~52 nm along the seafloor.
2) Underwater video images were viewed in real time on the support vessel by biologists familiar with the local deep-water fauna; images were collected and stored in digital format for analysis.
3) Series of still photographic images were taken concurrently with the video of hard-bottom assemblages of potential biological interest; photographs were also taken at intervals of soft-bottom habitats and of specific organisms for identification purposes.
4) Field notes and video images were reviewed and summarized to identify habitats and fauna; these summaries were compiled in GIS format and, with refined geohazards survey geophysical data, were used to produce a habitat map.
5) Series of still images were analyzed using Coral Point Count software to determine relative cover of hard versus unconsolidated substrates in eight areas of biological interest.
6) Areas were calculated for the same images and all organisms larger than 3-4 cm were enumerated; the resulting data were combined to produce density measurements of hard-bottom macrofauna in the eight areas of biological interest.

G. QA/QC

Decisions on all habitat identifications and transitions between habitats were finalized by the Principal Investigator following reviews of field transcripts, videotapes and DVDs copied from original videotapes. Identifications of organisms in photographs were made either by the P.I. or by graduate students trained by the P.I. Of the latter, those showing hard-bottom habitats with octocorals and sponges were reviewed by the P.I. for accuracy.

H. Personnel

Charles G. Messing – chief scientist, Nova Southeastern University (NSU)
John K. Reed – scientist, Harbor Branch Oceanographic Institution
Sandra D. Brooke – scientist, Florida Fish and Wildlife Research Institute
Bethany Basten – field assistant, NSU
Jessica Freeman – field assistant, NSU
Kirk Kilfoyle – field assistant, NSU

Brian Walker – GIS analyst, NSU
Vanessa Brinkhuis – photo analyst, NSU
David Portnoy – photo analyst, NSU

I. Itinerary

13 April 06 – Mobilization
14-17 April 06 – Field operations
18 April 06 – De-mobilization

IX. RESULTS

We identified six seafloor habitat categories. Figure 5 (and Appendix map 2) illustrates the distributional pattern of these habitats within the geohazards survey area and in the area to the north examined by ROV transects only. Unconsolidated sediment substrates recorded by video and still photography along ROV transects (lines and points) within the geohazards survey area correlate well with the smooth seafloor regions in the geohazards sidescan map. Similarly, hard-bottom substrates observed along ROV transects correlate well, with few exceptions, with areas of irregular topography in the geohazards sidescan map. As a result, smooth sidescan areas have been interpolated as unconsolidated sediment substrates, and most areas of irregular topography have been mapped as exposed high-cover hard bottoms. Exceptions—chiefly large-scale sedimentary features—are described below. North of the geohazards survey area, habitats have been interpolated as GIS polygons (hatched areas in Figure 5) from the patterns observed along the ROV transects. Although a continuum exists in exposed hard bottom from small bits of rubble <10 cm across isolated on unconsolidated sediment substrates to extensive areas of low- to moderate relief outcrops, boulders, slabs and pavements, we have followed SEAMAP guidelines in distinguishing two hard-bottom habitats based on a combination of the nature and extent of the exposed hard substrates and the associated attached macrofauna.

A. Fauna

1. Soft-bottom fauna

Appendix 1 lists all taxa identified on all substrates. Echinoderms, crustaceans and cnidarians dominate the macrofauna on unconsolidated sediment substrates, although many of the mobile forms also occur on low-relief hard bottoms. The commonest forms were the orange, multi-armed asteroid *Coronaster briareus* (Figure 6B), small galatheid crustaceans (squat lobsters) (Figure 6G), and a sea anemone tentatively identified as *Actinauge longicornis* (Figure 6A). This species lives on sediment substrates by surrounding a bolus of mud with its pedal disk; it also clings to hard substrates and is particularly common on scattered low-relief rubble and small outcrop exposures. Several unidentified species of burrowing anemones (Ceriantharia) were also observed but were never as common as recorded in the previous benthic video survey along the pipeline route to the west of the geohazards survey area (Messing et al. 2003). Chiefly isolated individuals of an unidentified pennatulid up to ~0.5 m tall were observed along the eastern portions of several transects at depths >900 ft (Figure 6F). A cidaroid urchin (?*Cidaris rugosa*) is common and widespread below 750 ft (Figure 6C), and ophiuroids were locally abundant ~~chiefly~~ below 850 ft (Figure 7D), with scattered individuals as shallow as 705 ft. Other echinoderms included several sea stars (probably including *Sclerasterias* sp. and *Astropecten* sp.) and the urchin *Echinus affinis* (Figure 6D). The small (<5 cm) symmetrical hermit crab *Pylocheles* sp. was sometimes common in deeper water (Figure 7A), and isolated typical paguroid hermit crabs were also occasionally observed. Widespread larger decapod crustaceans included the crabs *Bathynectes longispina* (Portunidae) (Figure 6E), *Cancer borealis* (Cancridae) and *Rochinia crassa* (Majidae).

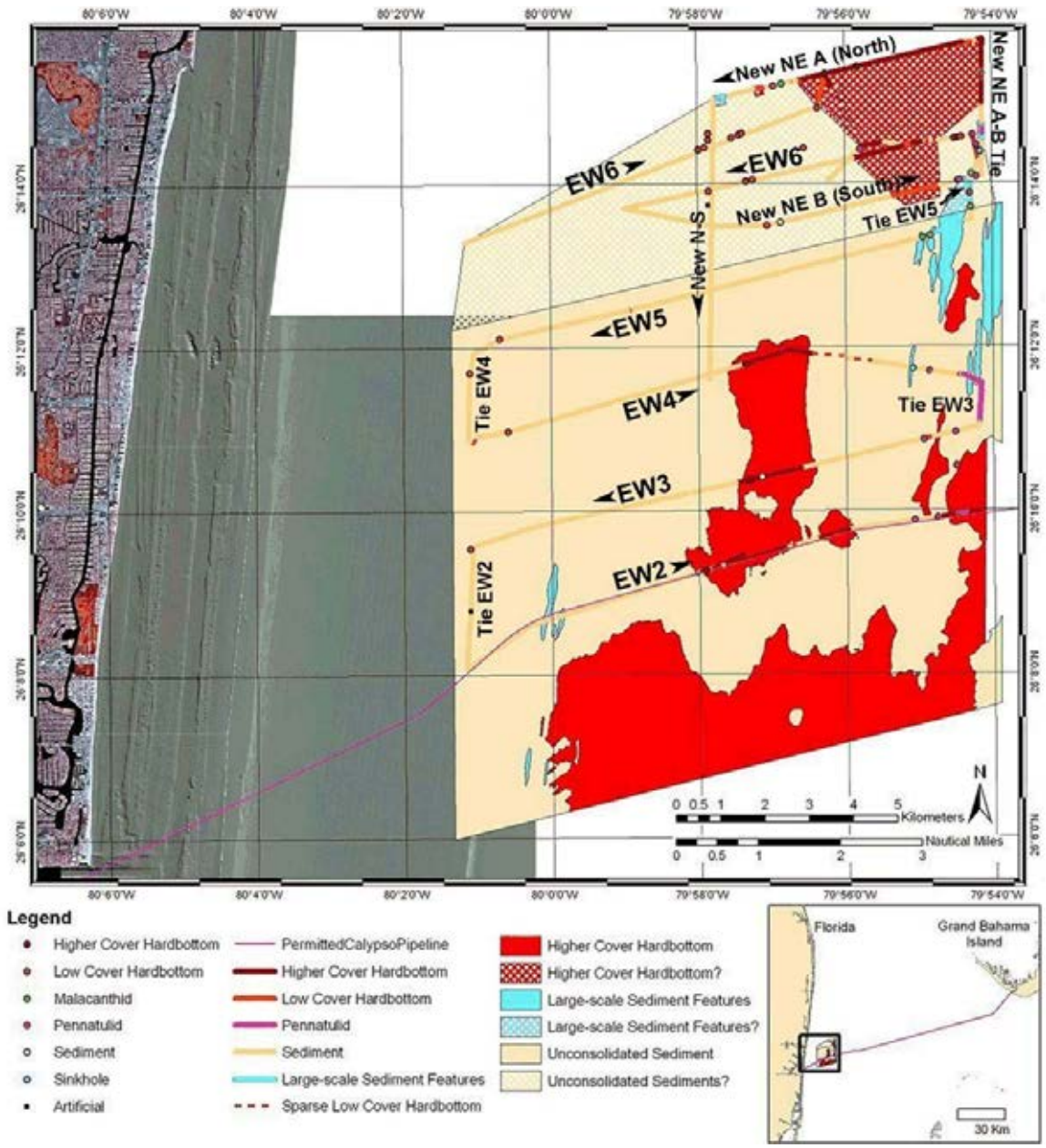

Figure 5. Benthic habitat map based on a combination of the benthic video survey along transect lines and refined sidescan data from the geohazards survey. Hatched GIS habitat polygons represent interpolations between transect lines north of the geohazards survey area. Arrowhead indicate the direction in which major transects were run. Transect EW6 was split due to sea conditions with the western half run west to east and the eastern half run east to west. Appendix 2 shows a larger version.

Flat sediment substrates were characterized by often dense populations of what appear to be numerous small slightly projecting tubes (perhaps sabellid polychaetes, which have been trawled in this general area)—described as “textured” in Messing et al. (2003). In the deeper, eastern portion of the study area, flat bottoms supported populations of unidentified “tufts”—either 1-2-cm bushy growths or 1-3-cm tall stalks with a cluster of fine radiating filaments that arise from the upper half of the stalk (Figure 7D, E). These organisms might represent worm tubes with epifauna or, perhaps, agglutinating foraminiferans, bryozoans or hydroids.

Fishes included the blind torpedo *Benthobatis marcida* (Narcinidae) (Figure 7B), Gulf Stream flounder *Citharichthys arctifrons* (Paralichthyidae) (Figure 7C), unidentified scorpionfishes (Scorpaenidae), at least one specie of skate (Rajidae), an armored searobin *Peristedion* sp. (Peristediidae), blueline tilefish *Caulolatilus microps* (chiefly burrows) (Malacanthidae), and a variety of small eels and small unidentified fishes (<8 cm long)(the latter possibly including shortnose greeneye, *Chlorophthalmus agassizi* [Chlorophthalmidae]). Two unidentified groupers were observed in the side cameras over open sediment, and one great northern tilefish *Lopholatilus chamaeleonticeps* (Malacanthidae) was observed adjacent to its burrow.

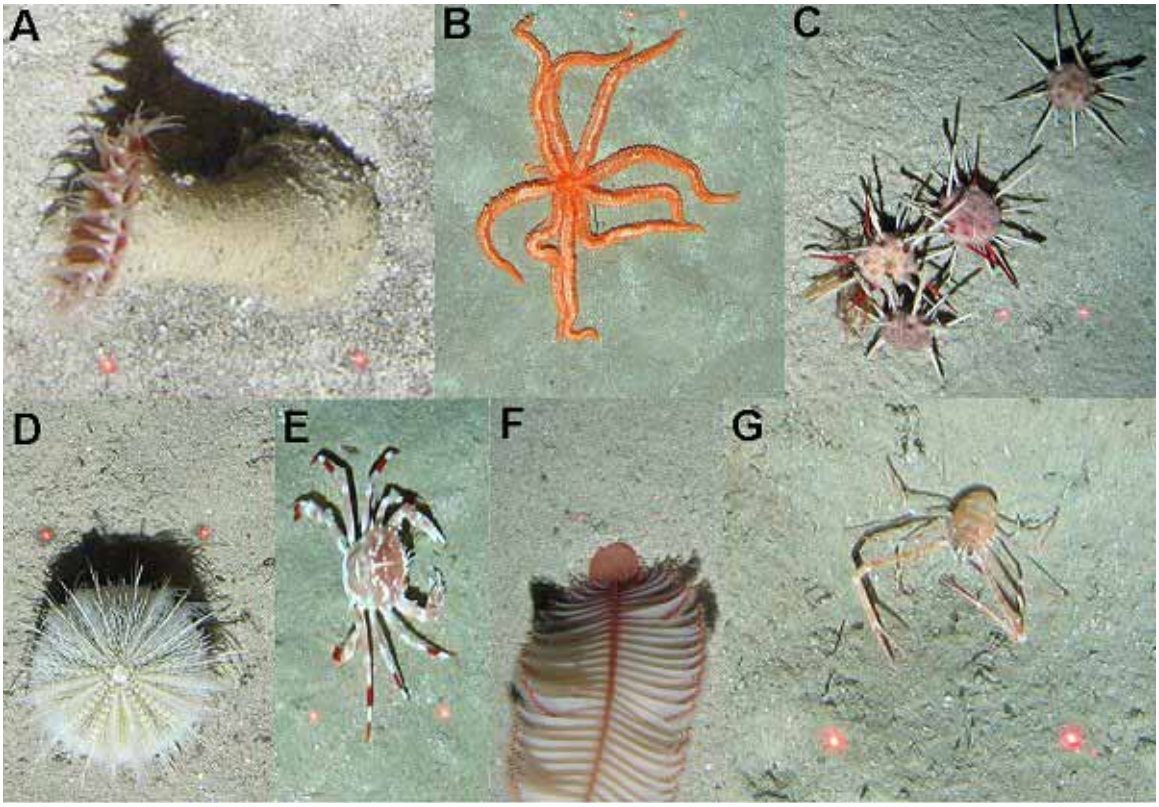

Figure 6. Representative macrofauna on sediment substrates. A.sea anemone ?*Actinauge longicornis* (Actiniaria), B. seastar *Coronaster briareus* (Asteroidea), C. pencil urchin ?*Cidaris rugosa* (Echinoidea), D. sea urchin *Echinus affinis* (Echinoidea), E. swimming crab *Bathynectes longispina* (Decapoda Brachyura), F. unidentified sea pen (Octocorallia Pennatulacea), G. galatheid squat lobster ?*Munida* sp. (Decapoda Anomura). Laser points are 8 cm apart; some have been relocated within the image to lie adjacent to the organism.

2. Hard-bottom fauna

A variety of sponges, including both hexactinellid glass sponges and demosponges, and cnidarians dominated the sessile fauna on hard substrates. Hexactinellids included *Aphrocallistes* sp. (Figure 8A), *Farrea* sp. (Figure 8D) and unidentified species. Demosponges included the fan sponge *Phakellia* sp. (Axinellidae), lithistid cup sponges (e.g., *Corallistes* sp.) (Figure 8F) and unidentified representatives of the families Pachastrellidae, Geodiidae and Petrosiidae (Figure 8F).

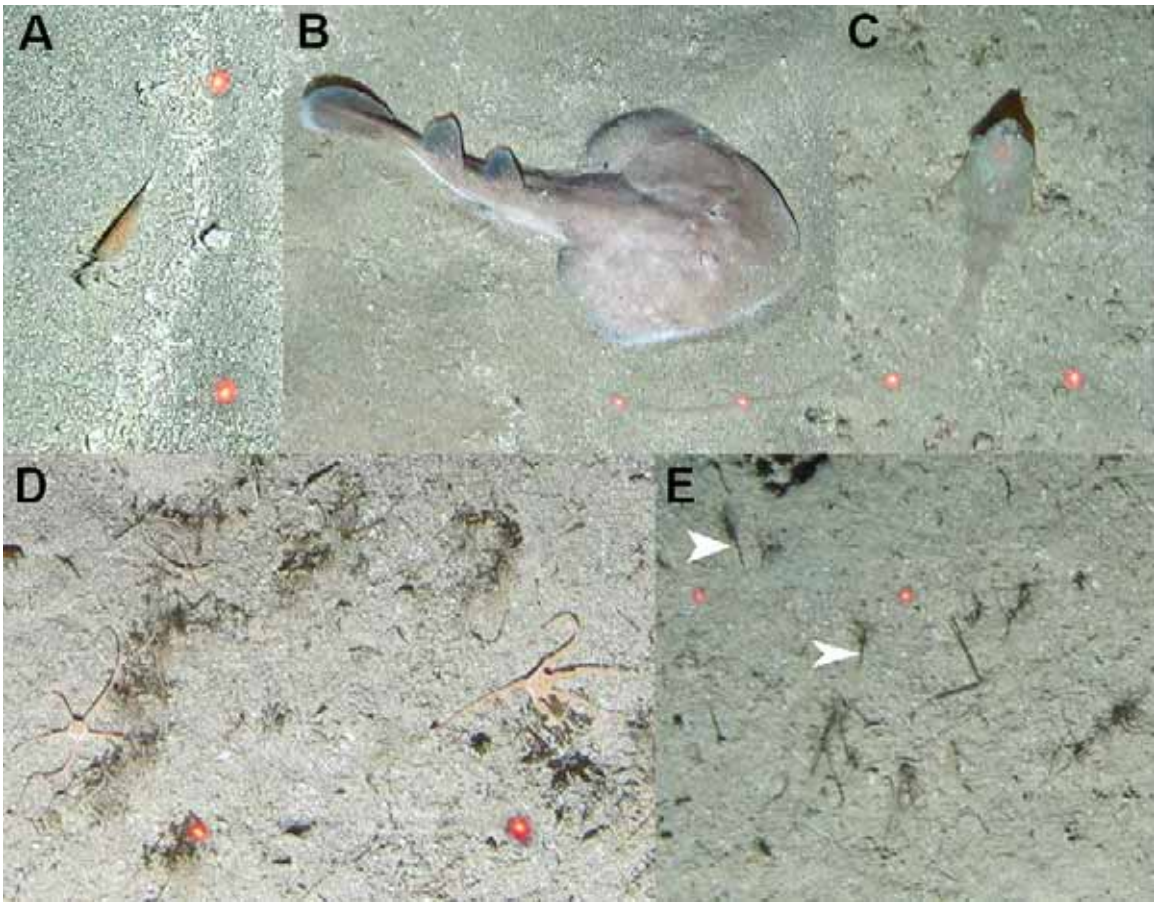

Figure 7. Additional representative macrofauna on sediment substrates. A. symmetrical hermit crab ?*Pylocheles* sp. (Decapoda Anomura), B. blind torpedo *Benthobatis marcida* (Chordata), C. Gulf Stream flounder *Citharichthys arctifrons* (Chordata), D. unidentified brittlestars (Ophiuroidea) with unidentified bushy "tufts," E. unidentified stalked "tufts."

A large pale pyriform geodiid was consistently the most massive sessile organism encountered (Figure 8C). Hydrozoan cnidarians were represented by a variety of small bushy or pinnate, chiefly thecate hydroids (Figure 8G) and a few small lace corals (Stylasteridae). Anthozoans included Actiniaria (sea anemones), Zoanthidea (zoanthids, colonial anemones), Antipatharia (black corals) and Octocorallia (soft corals, gorgonians, sea pens). The only stony corals observed were small solitary azooxanthellate cup corals (≤2 cm) (except for two small branching colonies on the fuselage of a sunken airplane). As noted above, the anemone ?*Actinauge longicornis* was particularly common on scattered low-relief rubble and small outcrop exposures (Figure 8H). In addition to ?*A. longicornis*, we observed the Venus flytrap anemone (Hormathiidae) (Figure 8D) and several unidentified taxa (e.g., white with a pink mouth, large pale with white clavate tentacle tips, large orange) (Figure 8D, F, G), which were common to abundant on high-cover hard substrates.

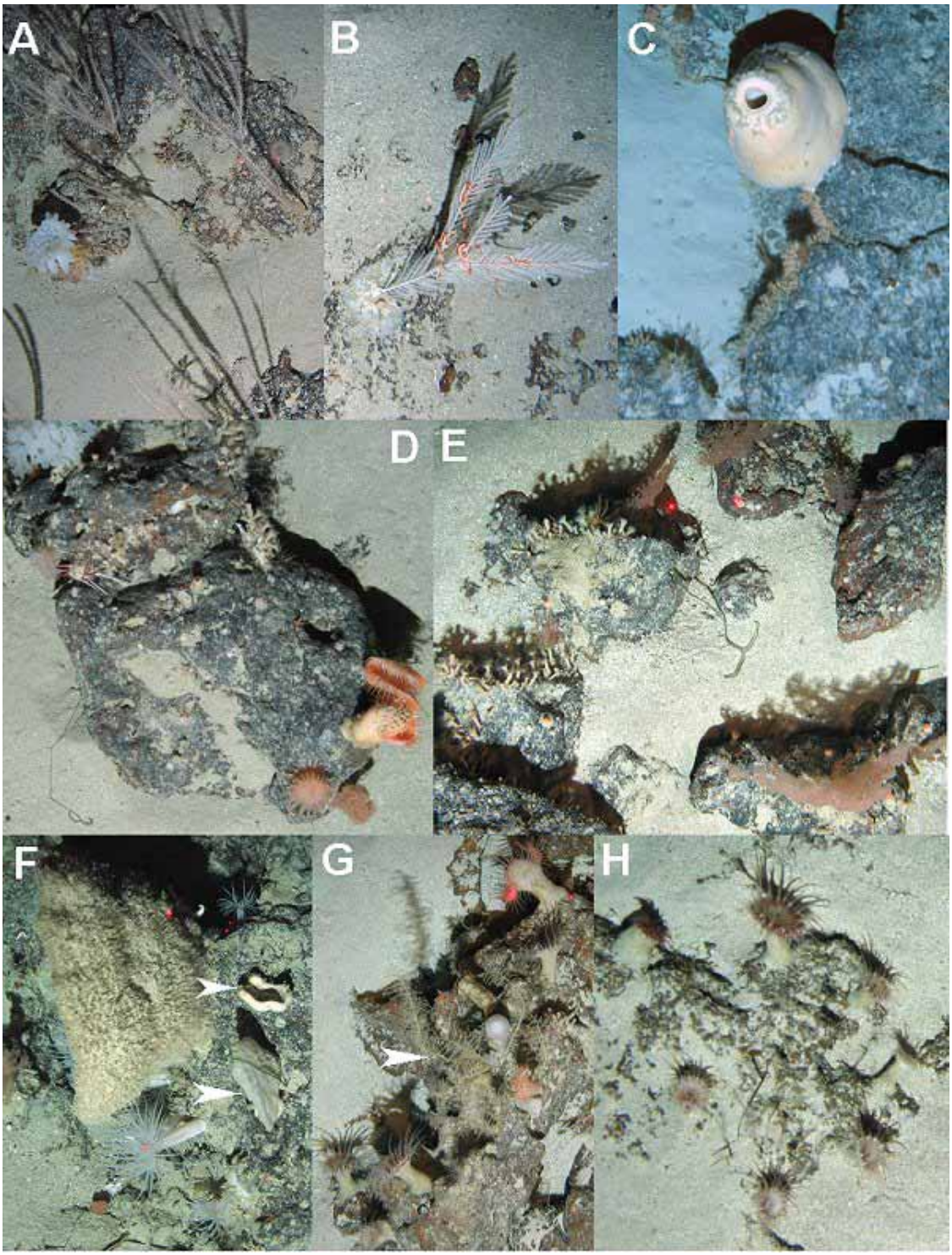

Figure 8. Representative hard-bottom invertebrates. A. bamboo corals *Isidella* sp. (Isididae) and glass sponge *Aphrocallistes* sp. (Hexactinellida), B. *Callogorgia americana* (Primnoidae) with asteroschematid ophiuroid, C. unidentified sponge (Geodiidae) and zoanthids, D. Venus flytrap anemone (Hormathiidae)(pair at lower right), glass sponge *Farrea* sp. (Hexactinellida) (top left), unidentified orange anemone and zoanthids, E. soft corals ?*Capnella nigra* (Nephtheidae)(lower right, top center), spoon worm (Echiura)(center) and zoanthids, F. lithistid cup sponge *Corallistes* sp. (top arrow), fan sponge *Phakellia* sp. (lower arrow) (Demospongiae), plate sponge (Pachastrellidae) (top left) and pink-mouthed anemones, G. unidentified hydroids (arrow) and anemones, H. anemones ?*Actinauge longicornis.*

Zoanthids included at least one species that formed thin encrusting sheets (to ~30 cm long) with projecting polyps, chiefly along edges of rocks and slabs (Figure 8E). Antipatharians were generally not common and most have not been identified. Field notes initially misidentified hydroids as antipatharians in some cases due to similar pinnate branching patterns of some taxa in both groups. A few spiral whip colonies of *Stichopathes luetkeni* were observed. Among octocorals, a small soft coral, probably *Capnella nigra*, was widespread on a variety of hard substrates (Figure 8E), including sediment-veneered pavement, scattered low-relief rubble, and larger irregular outcrops, blocks, slabs and pavements. The gorgonian fauna was dominated by a bamboo coral (Isididae, probably *Isidella* sp.)(Figure 8A) and a tall white sea plume (Primnoidae, probably *Callogorgia americana*) (Figure 8B). Colonies of these two organisms sometimes exceeded 50 cm in height and were typically the two tallest organisms encountered on hard substrates. Smaller fans belonging to the Paramuriceidae were uncommon. A species of spoon worm (Echiura, probably Bonellidae) often occurred in abundance, with its sausage-shaped body hidden below the seafloor, perhaps in a rock crevice, and its slender elongated Y-tipped greenish proboscis (up to ~1 m in length) along the sediment (Figure 8E).

Among the more mobile organisms, echinoderms included sea urchins and asteroids (other than *Coronaster briareus*) also found on sediment, abundant small reddish ophiuroids and a small psolid sea cucumber (Holothuroidea). Mollusks included occasional trochid gastropods (*Calliostoma* sp.) and chitons. Though not directly associated with hard substrates, antedonid crinoids (feather stars) and euryalous ophiuroids (snake stars, probably *Asteroschema* sp.) were observed clinging among branches of isidid and primnoid octocorals (Figure 8B).

The commonest fish typically associated with hard substrates was the blacktail codling *Laemonema melanurum* (Moridae) (Figure 9B). Others included an unidentified anthiine similar to the streamer bass *Hemanthias aureorubens* (Serranidae) (Figure 9C), blackbelly rosefish *Helicolenus dactylopterus* (Sebastidae) (Figure 9A), unidentified scorpionfishes (Figure 9D) and two larger fishes (30-60 cm)—one possibly a snowy grouper *Epinephelus niveatus* (Serranidae)—seen only in side cameras. *H.dactylopterus*, other scorpaenids, some small serranids and hakes (Phycidae) were seen in association with artificial substrates (airplane and boat wrecks).

B. Habitat categories

1. Sediment substrates – Unconsolidated mud or sand substrates. Most of the seafloor observed along the ROV transects (tan lines in Figure 5) consisted of obsolete (inactive) rippled muddy sand (Figure 10A) alternating with areas of flat bioturbated sediment characterized by scattered small low mounds, depressions and small tubes or tufts (Figure 10B), described above. In many areas, the rippled sediment formed low "platforms" elevated ~10-30 cm above flat bioturbated areas. This substrate correlates well with the smooth areas of the sidescan map (pale tan areas), described in the geohazards survey as low-reflectivity sandy bottom covered by a variety of sediment bedforms including mega-ripples, 3-dimensional sand waves, comet marks and sand ribbons. To the north of the geohazards survey area, sediment substrates observed along ROV transect lines have been extrapolated as unconsolidated sediment polygons. Orange dots in the habitat map each represent an individual bit of rubble, small rock (chiefly <30 cm across) or small (<1 m^2) low-relief patch of exposed hard bottom isolated on otherwise unconsolidated sediment substrates. Such islets of hard substrate are either barren of macrofauna or support small hydroid colonies or a species of sea anemone (?*Actinauge longicornis*) that also commonly anchors on unconsolidated substrates by surrounding a bolus of sediment with its pedal disk. None of these isolated hard substrates were large or extensive enough to qualify as hard-bottom habitat under agency guidelines.

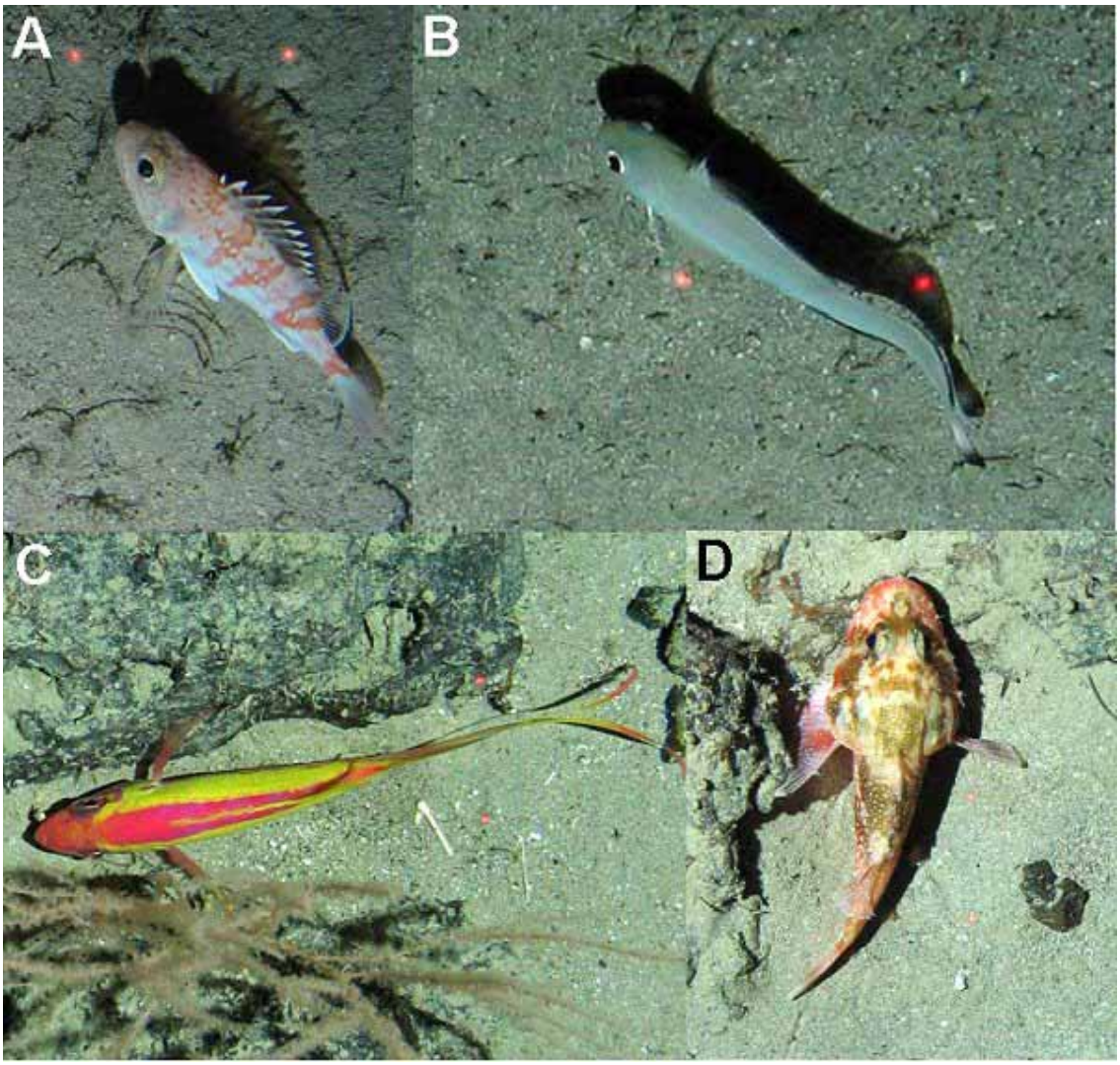

Figure 9. Fishes chiefly associated with hard-bottom substrates. A. blackbelly rosefish *Helicolenus dactylopterus* (Sebastidae), B. blacktailed lingcod *Laemonema melanurum* (Moridae), C. unidentified anthiine (Serranidae), D. unidentified scorpionfish (Scorpaenidae).

2. Large-scale sediment features – In the initial geohazards sidescan map, a few areas that appeared as irregular topography and were considered as possible hard substrate proved, in the refined geohazards data, to be areas of marine sands with complex sediment bedform patterns—large sand waves and conical erosional pits—and evidence of significant localized erosions (blue in Figure 5). ROV observations referred to often circular depressions ~6-30 m across with 20-30º slopes and vertical relief of up to 8 m. The majority lacked any exposure of hard substrates. However, depression slopes and floors in some cases revealed discontinuous areas of white, apparently consolidated clayey material and, rarely, rubble or a few larger rocks. Attached macrofauna were absent or limited to anemones that also occurred on sediment. The small narrow blue areas in the southwestern quadrant have been mapped as this habitat based on geohazards data. However, video observations transitting this habitat along transect EW2 (the pipeline route) revealed no features distinguishing it from the surrounding sediments.

3. Tilefish burrows – We observed about 7 burrows apparently excavated by the blueline tilefish, *Caulolatilus microps* (green dots in figure 5 and Appendix 2). Most were associated with the slopes of some of the large depressions in the northeastern quadrant of the survey area. We also observed a single great northern tilefish (*Lopholatilus chamaeleonticeps*) at its burrow.

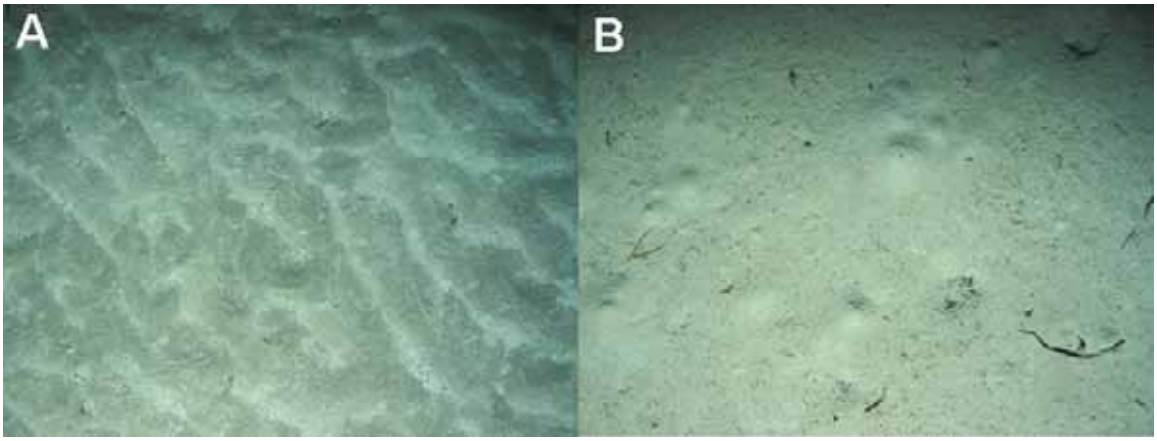

Figure 10. Representative unconsolidated sediment substrates. A. Obsolete rippled sediment, B. Flat textured bioturbated sediment.

4. Pennatulids – Observations of one or a few individuals (Figure 6F) have been mapped as purple dots in Figure 5. Most of Tie EW3 and the eastern end of EW4 have been mapped as continuous pennatulid habitat (purple line) to reflect the repeated appearance of these organisms. However, individuals were typically widely scattered with a maximum of two visible in the same video frame only once. Almost all specimens were observed in 930 ft or greater, with single records in 890 (possibly a different species) and 919 ft. We have not delineated a pennatulid habitat polygon because of their absence from the expected depth range along EW5 and EW6 and their restriction to the extreme east end of EW3.

5. Low-cover hard bottom – This habitat consisted of scattered clusters of rubble (to ~10 cm) or small rocks (chiefly to 30 cm), often in patches a few meters across, rarely in more extensive fields, and separated by expanses of sediment, occasionally accompanied by a few low-relief rocks up to 0.8 m across and rare veneered slabs or pavements to 1 m across (Figure 11A, C, E). Isolated individual bits of rubble or small rocks have been mapped as dots on otherwise unconsolidated sediments. In most cases, this substrate supports a low-richness fauna of anemones, zoanthids, nephtheid soft corals (probably *Capnella* sp.) and hydroids. A few areas supporting greater and more complex macrofaunal richness, e.g., isidid or primnoid octocorals and sponges, have been treated as high-cover hard bottom (see below) despite the relatively sparse available hard bottom. We have mapped no polygons encompassing this habitat because almost all fall as isolated occurrences on unconsolidated substrates or in patchy association with high-cover hard bottoms. A few transect sections mapped as dashed orange and tan lines in Figure 5 (e.g., part of EW4) represent exposures of low-cover hard bottom too abundant to map as individual points but too widely separated by areas of sediment to map as continuous hard bottom.

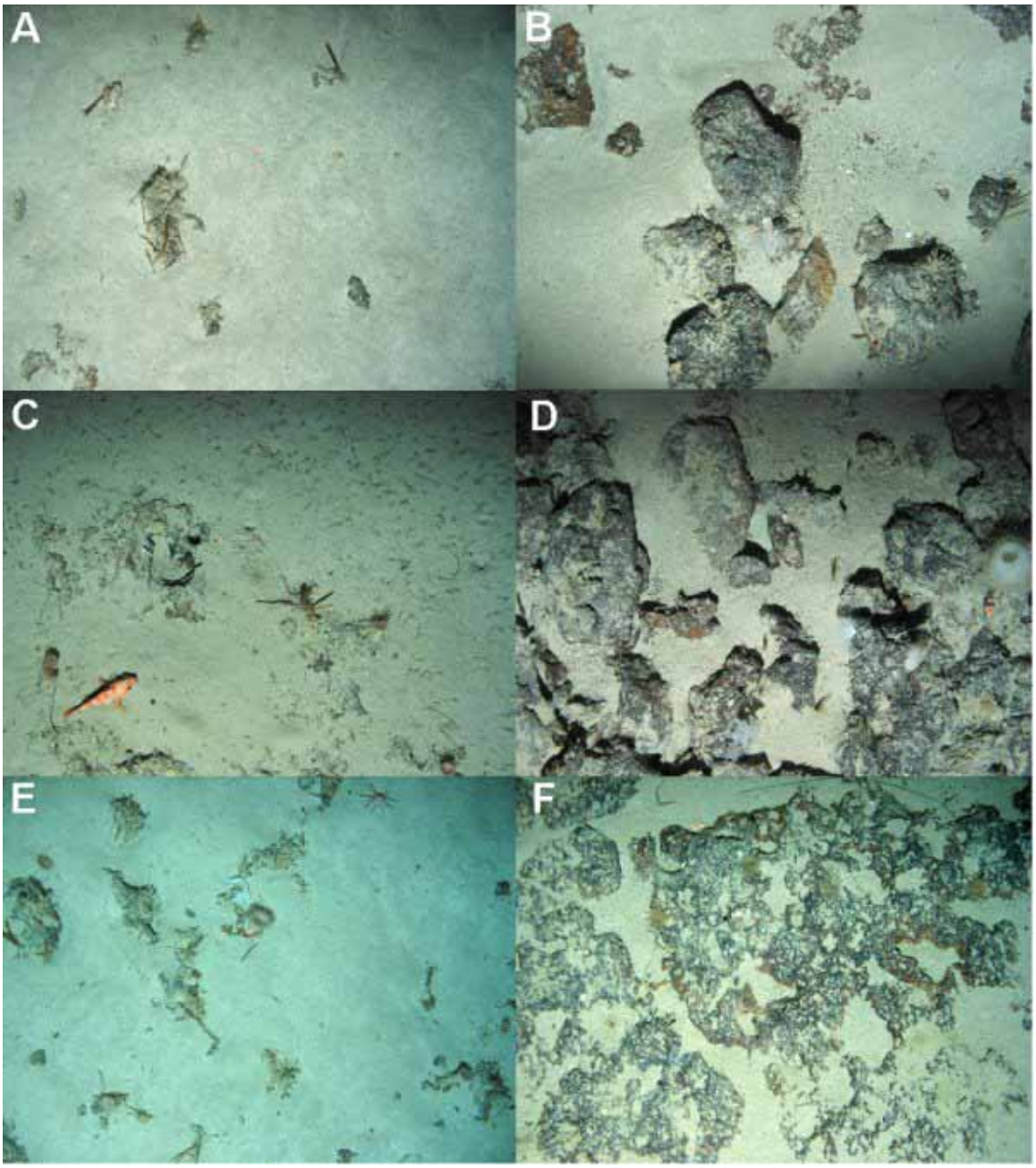

Figure 11. Representative low-cover (A, C, E) and high-cover (B, D, F) hard-bottom substrates.

6. High-cover hard bottom – This habitat consisted of low- to moderate-relief hard bottom characterized by phosphoritic limestone outcrops, pavement and slabs, each chiefly <2 m across (rarely to 3 m), with varying amounts of rubble and small to large rocks, frequently in patches separated by expanses of sediment and intermixed with low-cover hard-bottom areas of scattered rubble, small rocks and outcrops (Figure 11B, D, F). With the exceptions noted above, we have mapped all hard bottom identified in the geohazards survey as high-cover (red areas) because of the irregular, complex, often small-scale patchy variations in the distribution of low- versus high-cover habitats. The geohazards survey describes the irregular topography in the sidescan map as paleo-carbonate outcrops and phosphoritic gravel-boulder lag deposits interspersed

with a discontinuous sand veneer. The sand veneer observed as unconsolidated rippled or flat bioturbated sediment between or surrounding exposures is almost entirely too thick to support attached macrofauna.

C. Transect Habitat Summary

This section summarizes habitats observed along the ROV transects. Latitudes and longitudes are those used to map points at which habitats change in Figure 5, or to identify point locations of, for example, pennatulids, tilefish burrows or small isolated occurrences of hard bottom. With the exceptions of the most common benthic invertebrates (i.e., the asteroid *Coronaster briareus*, cidaroid echinoids, ophiuroids and galatheid crustaceans) and tilefish, mobile macrofaunal invertebrates (e.g., crabs) and fishes have not been included in the habitat summary, because the majority occur as widely scattered individuals throughout the survey area. Although small (<8-cm-long) unidentified fishes did tend to occur in larger numbers on hard bottoms, we did not quantify this tendency and observed only a handful of concentrations in which multiple individuals were visible in a single field of view.

<u>1. EW6 – West to East</u>
26º 13.292'N 80º 01.161'W to 26º 14.944'N, 79º 56.365'W, depth range 618-865 ft
From 618 to 667 ft, the substrate is flat bioturbated sediment (scattered small low mounds and depressions) with numerous small tubes. Obsolete rippled muddy sand appears in 667 ft and alternates with flat areas of bioturbated textured sediment to 865 ft. In some areas, the rippled sediment forms low waves elevated up to ~15 cm above the flat bioturbated areas. A few isolated small bits of rubble and a few small low-relief outcrops appear below ~800 ft. Dominant organisms on sediment are *Coronaster briareus*, cerianthid anemones,?*Actinauge longicornis* and galatheids. The first cidaroid appeared in 853 ft.

26º 14.603'N, 79º 57.438'W; depth 842 ft.
Excavation with a large (~0.8-m long) fish, probably a great northern tilefish, *Lopholatilus chamaeleonticeps*.

26º 14.944'N, 79º 56.365'W to 26º 14.524'N, 79º 54.735'W; depth range 845-896 ft
Substrates range from areas of widely scattered rubble (8-10 cm) to crowded chiefly low-relief outcrops, small to large rocks and rubble, separated by expanses of obsolete rippled sediment and flat bioturbated sediment as above. Some flat sediment areas support numerous fine (1-2-cm) tufts. One pennatulid was seen. We observed low- to moderate-relief phosphoritic outcrops, slabs and pavement to >1 m across at one locality (26º 14.458'N, 79º 55.215'W). Hard-substrate organisms include demosponges (e.g., *Phakellia* sp., Pachastrellidae), *A. longicornis*, Venus flytrap anemone (Hormathiidae), echiurans, Isididae (probably *Isidella* sp.), Nephtheidae, (?*Capnella nigra*) and unidentified gorgonians.

26º 14.524'N, 79º 54.735'W to 26º 14.548'N, 79º 54.518'W; depth range 895-900 ft
Obsolete rippled sediment alternating with weakly bioturbated sediment with small tubes. Dominant organisms are cidaroids and sometimes numerous active small ophiuroids.

26º 14.548'N, 79º 54.518'W to 26º 14.590'N, 79º 54.268'W; depth range 898-910 ft
The same unconsolidated sediment bottoms as above, including elevated low sand waves with obsolete rippled sediment, but with occasional scattered low-relief rocks, outcrops, a 1-m slab, an isolated 0.5-m boulder, and, at 26º 14.556'N, 79º 54.479, an isolated cluster of low boulders to 0.6 m across, <0.3 m high. Dominant organisms are cidaroids and ophiuroids, with some ?*Capnella nigra* on the one isolated cluster of low boulders. One pennatulid was observed (26º 14.590'N, 79º 54.268'W).

2. EW6 – East to West, Repeated portion of transect

26º 14.475'N, 79º 55.130'W to 26º 14.303'N, 79º 55.894'W; depth range 851-865 m
Rubble in rippled sediment becomes more crowded, with larger rocks 20-50 cm across, low pavement and slabs to 1.8 m across alternating with rippled sediment with sparse rubble and isolated rocks. Dominant fauna varies from sparse to numerous and includes sponges (*Phakellia* sp., *Aphrocallistes* sp., Pachastrellidae), numerous anemones, ?*Capnella nigra*, Isididae and occasional antipatharians up to 80 cm.

26º 14.303'N, 79º 55.894'W to 26º 13.712'N 79º 58.991'W; depth range 867-766 ft
Flat bioturbated sediment alternates with fine tubes and elevated obsolete rippled sediment. Hard substrates consist of a single 30-cm rock with an anemone, and an isolated flat barren outcrop ~0.75 m across. Dominant organisms include *C. briareus*, ?*A. longicornis*, galatheids, cidaroids and ophiuroids. The last cidaroid was seen in 860 ft.

3. Tie EW5 – North to South

26º 14.590'N, 79º 54.268'W to 26º 14.276'N, 79º 54.189'W; depth range 912-928 ft.
Obsolete rippled sediment alternates with flat sediment with small polychaete tubes. Hard substrates consist of ~5 very widely scattered small flat outcrops or small rocks <30 cm across. Dominant organisms include ?*A. longicornis*, ?*Capnella nigra* and cidaroids. Three pennatulids were observed at 26º 14.465'N, 79º 54.214'W in 928 ft.

26º 14.386'N, 79º 54.165'W; depth 927 ft.
Depression, ~8 ft vertical relief, diameter ~30 ft estimated from sonar. No hard substrates visible.

26º 14.276'N, 79º 54.189'W to 26º 14.069'N, 79º 54.300'W; depth range 927-934 ft
Alternating obsolete rippled sediment and flat sediment with one cluster of a few small 20-cm rocks and, at 26º 14.276'N, 79º 54.189'W, a cluster of rocks, flat slabs and low outcrops to 1.3 m across with many small fish. Hard substrates have anemones, ?*Capnella nigra* and cidaroids.

26º 14.113'N, 79º 54.285'W; depth 934 ft
Obsolete rippled sediment with a possible *Caulolatilus* tilefish (in side camera) and a cluster of anemones.

26º 14.069'N, 79º 54.300'W to 26º 13.708'N, 79º 54.297'W; depth range 927-948 ft
Series of large circular depressions ~30-100 ft across with sharp rims and 20-30° slopes; maximum vertical relief 930-948 ft; chiefly obsolete rippled sediment with areas of flat sediment with fine tubes; flat white outcrop or consolidated clayey sediment on floor of one depression. Organisms include clusters of anemones and a cerianthid.

26º 13.708'N, 79º 54.297'W to 26º 13.557'N, 79º 54.294'W; depth range 927-932 ft.
Alternating obsolete rippled and flat sediment with tubes. Organisms include ophiuroids and an asteroid. A possible tilefish burrow is visible in one side camera.

4. EW5 – East to West

26º 13.557'N, 79º 54.294'W to 26º 13.513'N, 79º 54.420'W; depth 927 ft
Obsolete rippled sediment.

26º 13.513'N, 79º 54.420'W to 26º 13.325'N, 79º 54.998'W; depth range 914-941 ft
Alternating obsolete rippled and flat sediment with tubes and some burrows. Large depressions with some exposed consolidated clay or barren white limestone in slopes; 20-40 ft across with a maximum vertical relief of 914-941 ft. Organisms on sediment include cidaroids and asteroids.

26º 13.359'N, 79º 54.846'W to 26º 13.336'N, 79º 54.950'W; depth range 914-941 ft
Two *Caulolatilus* tilefish burrows in slopes of depression.

26º 13.325'N, 79º 54.998'W to 26º 11.974'N, 80º 00.984'W; depth range 908-663 ft
Obsolete rippled sediment alternating with flat textured sediment with small tubes and weak bioturbation; a few isolated bits of rubble with no attached fauna; long low sand waves noted in 793-771 ft. Dominant organisms from 905-815 ft include *C. briareus*, asteroids, ophiuroids, cerianthids and galatheids. Shallower than this, the asteroids and ophiuroids disappear and are replaced by ?*A. longicornis*, which becomes more abundant toward the end of the transect.

<u>5. Tie EW4 – North to South</u>
26º 11.974'N, 80º 00.984'W to 26º 10.885'N, 80º 01.124'W; depth range 670-654 ft
Chiefly weakly bioturbated sediment with small cones and depressions. Hard substrates consist of a few isolated clusters of small bits of rubble <8 cm, and one 15-cm rock with anemones or hydroids. Dominant organisms on sediment are *C. briareus*, ?*A. longicornis*, cerianthids and galatheids.

<u>6. EW4 – West to East</u>
26º 10.885'N, 80º 01.124'W to 26º 10.823'N, 80º 01.065'W; depth range 665-670 ft
Sparsely bioturbated sediment.

26º 10.823'N, 80º 01.065'W to 26º 10.920'N, 80º 01.809'W; depth range 670-681 ft
Sparsely bioturbated sediment with isolated clusters or individual pieces of small low-relief rubble chiefly <10 cm, rarely to 20 cm and a single cluster of low-relief rocks & slabs ~ 3 m across with hydroids and anemones. *C. briareus* and galatheids are the commonest organisms on the sediment.

26º 10.920'N, 80º 01.809'W to 26º 11.801'N, 79º 57.360'W; depth range 699-829 ft
Flat, sparsely bioturbated sediment alternating with patches of rippled sediment. Dominant organisms are *C. briareus*, galatheids and ?*A. longicornis*.

26º 11.801'N, 79º 57.360'W to 26º 11.916'N, 79º 56.463'W, depth range 826-880 ft
Areas or clusters of low-relief tan to brown rubble, rocks, boulders, and veneered slabs; pavements to 2 m across separated by expanses of chiefly flat sediment with small tubes. Fauna includes the hexactinellid sponge *Aphrocallistes* sp., *Phakellia* sp., lithistid, pachastrellid and geodiid demosponges; isidid, primnoid (*Callogorgia americana*) and nephtheid (?*Capnella nigra*) octocorals, hydroids, anemones and echiurans. Organisms on sediment include *C. briareus* and cidaroids.

26º 11.916'N, 79º 56.463'W to 26º 11.819, 79º 55.619'W; depth range 883-934 ft.
Flat or rippled sediment with isolated clusters or individual small rocks and rubble, chiefly <20 cm, with an occasional rock or isolated flat slab to ~1 m. Organisms are chiefly anemones, ?*C. nigra*, echiurans and cidaroids, with a few small gorgonians and a sponge at one site.

26º 11.819'N, 79º 55.619'W to 26º 11.652'N, 79º 54.461'W; depth range 936-950 ft
Flat, sparsely bioturbated sediment with some areas of obsolete ripples. Organisms include anemones (including one on a single isolated bit of rubble) and abundant ophiuroids. Two organisms described as 50-cm-tall octocorals most likely represent pennatulids.

26º 11.738'N, 79º 55.099'W; depth range 943-954 ft
A large depression with tiny rocks and a few rocks up to 1 m across; maximum vertical relief 15 ft. Organisms are cidaroids and anemones.

26º 11.738'N, 79º 55.099'W to 26º 11.652'N, 79º 54.461'W, depth range 943-950 ft
Flat sediment with sparse bioturbation, few ripples. Organisms are ophiuroids, anemones, cidaroids. Two pennatulids 20 and 50 cm tall were observed on the sediment (only one visible on tape) at 26º 11.717'N, 79º 54.952'W in 943 ft.

26º 11.652'N, 79º 54.461'W to 26º 11.651'N, 79º 54.412'W; depth range 950-952 ft
A few isolated small rocks (5-30 cm) and few clusters of small rocks and low veneered slabs (to 0.75 m) with numerous ?*A. longicornis* and a flytrap anemone. ?*A. longicornis* was also observed on sediment; ophiuroids were less abundant than earlier.

26º 11.651'N, 79º 54.412'W to 26º 11.538'N, 79º 54.163'W; depth range 950-952 ft
Alternating slightly elevated sand waves with obsolete rippled sediment and flat areas of sediment with small tubes. Organisms include abundant ?*A. longicornis* on sediment, from 2-3 to 12 m^{-2} (with one on a single isolated rock); also galatheids and several pennatulids—up to 2 in one field of view, otherwise widely isolated; some were visible in the side-looking camera.

<u>7. Tie EW3 – North to South</u>
26º 11.555'N, 79º 54.166'W to 26º 11.052'N, 79º 54.194'W; depth range 952-959 ft.
Flat sediment with little bioturbation, some rippled sand waves. Organisms include numerous ?*A. longicornis*, up to 6-7 m^{-2}, and cidaroids. A total of 18 pennatulids were noted along this transect over a period of 33 min.

26º 11.052'N, 79º 54.194'W to 26º 11.019'N, 79º 54.216'W; depth range 963-964 ft
Sediment with a cidaroid to end of transect.

<u>8. EW3 – East to West</u>
26º 11.019'N, 79º 54.216'W to 26º 10.884'N, 79º 54.876'W; depth range 963-966 ft
Alternating flat and rippled sediment; occasional bioturbation with a possible veneered hardground in one area. Dominant organisms are anemones, cidaroids, ophiuroids, galatheids and, in one area, pennatulids (26º 10.957'N, 79º 54.521'W).

26º 10.884'N, 79º 54.876'W to 26º 10.871'N, 79º 54.932'W; depth range 966-968 ft
Scattered clusters of low-relief rocks and slabs a few meters across separated by expanses of sediment; rocks up to 0.8 m across & pavement 1.5 m across; mostly barren with little fauna. Organisms consist of a few anemones, a flytrap anemone, echiurans and cidaroids.

26º 10.871'N, 79º 54.932'W to 26º 10.544'N, 79º 54.508'W; depth range 963-896 ft

Alternating obsolete rippled sediment and flat, firm, textured (with tiny tufts, worm tubes) bioturbated (small mounds and depressions) sediment. Organisms include galatheids, asteroids, a few *C. briareus* and patches of abundant ophiuroids. Anemones were absent from much of this segment. One pennatulid was seen in a side camera (26º 10.867'N, 79º 54.948'W).

26º 10.544'N, 79º 54.508'W to 26º 10.521'N, 79º 56.617'W; depth range 896-889 ft.
Chiefly rippled sediment with a few scattered rocks, slabs and low-relief hard bottom with anemones.

26º 10.521'N, 79º 56.617'W to 26º 10.337'N, 79º 57.500'W; depth range 871 [initial depth not recorded; probably 889 ft] to 856 ft.
Low-relief rocky outcrops, scattered rocks & rubble, rubble fields, slabs up to 2 ft across and sediment-veneered pavements, separated by expanses of flat sediment with tiny tufts. Hard-bottom organisms include sponges (e.g., Pachastrellidae, Geodiidae, lithistids, *Phakellia* sp., cup sponges), octocorals (e.g., Isididae, Primnoidae, other unidentified gorgonians, and ?*C. nigra*), numerous anemones, flytrap anemone, an antipatharian, echiurans, cidaroids and asteroids.

26º 10.337'N, 79º 57.500'W to 26º 09.583'N, 80º 01.061'W; depth range 867-701 ft.
Sparsely bioturbated sediment with small tubes alternating with obsolete rippled sediment. Organisms include a few anemones, cerianthids, *C. briareus*, ophiuroids and galatheids.

26º 09.821'N, 80º 00.218'W; depth 734 ft.
The ship and ROV diverted from the transect to investigate a sonar return that proved to be a single engine (Grumman?) Avenger FT-87 with *Swiftia* sp. and other unidentified gorgonians, hydroids, flytrap anemone and two small branching coral colonies (noted as *Lophelia* on transcript, but depth probably too shallow).

<u>9. Tie EW2 – North to South</u>
26º 09.583'N, 80º 01.061 to 26º 08.606'N, 80º 00.309'W; depth range 701-752 ft.
Sparsely bioturbated sediment with mounds, depressions and clusters of small tubes; some debris with hydroids and a small cluster of <10-cm rubble (26º 09.547'N, 80º 01.104'W) in 692 ft; a small sailboat in 681 ft (26º 08.800'N, 80º 01.105'W) with numerous anemones on the adjacent substrate and anemones including some hormathiids on its hull. Several fishes around the wreck adjacent to the substrate were tentatively identified as tilefish but are most likely phycid hakes. Blackbelly rosefish (*Heliconlenus dactylopterus*) and some small serranids were also observed.

<u>10. EW2 – West to East (Western portion)</u>
26º 08.606'N, 80º 00.309'W to 26º 09.243'N, 79º 58.035'W; depth range 752-840 ft.
Flat bioturbated sediment (mounds, burrows) with small tubes and fine tufts alternating with raised areas of obsolete rippled sediment. Common macrofauna include *C. briareus*, ophiuroids and galatheids; cidaroid urchins appeared at 768 ft.

26º 09.243'N, 79º 58.035'W to 26º 09.462'N, 79º 57.414'W; depth range 840-847 ft.
Abundant to scattered 10-20-cm rubble, small and large rocks (rarely to 1 m), low-relief slabs and irregular outcrops separated by expanses of sediment. Hard-bottom organisms include sponges (e.g., *Aphrocallistes* sp., *Phakellia* sp.), hydroids, octocorals (Nephtheidae, Primnoidae, Isididae), anemones and echiurans. Organisms on sediment substrates include *Coronaster briareus* and at least one other asteroid species (perhaps *Sclerasterias* sp.). The transect was halted and the ROV lifted off bottom at 26º 09.462'N, 79º

57.414'W to proceed to the eastern end of EW2 and work back to the west because of deteriorating sea conditions.

11. EW2 – East to West (Eastern portion)
26º 09.978'N, 79º 54.193'W to 26º 09.899'N, 79º 54.811'W; depth range 925-970 ft
Rubble, rocks (8-30 cm), boulders, some slabs, pavement and veneered hard bottom; relief chiefly 1-2 ft (up to 3 ft); some expanses of sediment. Hard-bottom organisms include various sponges (e.g., hexactinellids, *Phakellia* sp., pachastrellids), flytrap anemone, Isididae, Primnoidae, numerous anemones and ?*C. nigra* on small rubble, and a spiral whip antipatharian (*Stichopathes luetkeni*). A few pennatulids were observed on sediment substrates between hard-bottom areas. We observed hard-bottom habitats along a small portion of this transect where the geohazards sidescan data showed smooth bottom.

26º 09.899'N, 79º 54.811'W to 26º 09.766'N, 79º 55.985'W; depth range 964-970 ft.
Obsolete rippled sediment with a few scattered pennatulids, anemones and one or two isolated bits of rubble (5-10 cm).

26º 09.766'N, 79º 55.985'W to 26º 09.677'N, 79º 56.289'W; depth range 939-912 ft.
Chiefly scattered low-relief hard bottom – rubble, 10-30-cm rocks and slabs separated by sediment expanses. Organisms include a few hexactinellid and other sponges, anemones, flytrap anemone, ?*C. nigra*, hydroids, one isidid octocoral and cidaroids.

26º 09.677'N, 79º 56.289'W to 26º 09.650'N, 79º 56.407'W; depth 914 ft.
Small area of more extensive hard bottom – low-relief pavement, with flytrap anemone, sponge, Isididae and cidaroid urchin.

26º 09.650'N, 79º 56.407'W to 26º 09.648'N, 79º 56.419'W; depth 916 ft.
Sediment bottom with a few small rocks.

26º 09.648'N, 79º 56.419'W to 26º 09.572'N, 79º 56.717'W; depth range 916-908 ft.
Flat sparsely bioturbated sediment with no ripples. Organisms include a few cidaroids and an asteroid.

26º 09.572'N, 79º 56.717'W to 26º 09.547'N, 79º 56.846'W; depth range 907-904 ft.
Flat sediment with tiny tufts, with two small isolated areas of hard bottom – a small area with low-relief rocks and slabs to 1 m across, and another with a few widely isolated small rocks & rubble. Organisms are restricted to anemones, hydroids and ?*C. nigra*. A large manmade object, possibly the hull of a small boat was noted off camera. Depths were not written down at the very end of this tape and the very beginning of the following tape, and the microphone had stopped working, which accounts for the gap in depth between this segment and the next.

26º 09.547'N, 79º 56.846'W to 26º 09.273'N, 79º 57.872'W; depth range 896-838 ft.
Low-relief, sediment-veneered irregular outcrops, slabs and pavements up to a few meters across and up to ~0.3 m high with 10-20-cm rubble, larger cobbles and small boulders, separated by expanses of sparsely bioturbated sediment with fine tufts. Organisms include pachastrellids sponges, anemones, hydroids, Isididae and Primnoidae.

26º 09.273'N, 79º 57.872'W to 26º 09.260'N, 79º 57.918'W; depth 845 ft.
Flat, sparsely bioturbated sediment.

12. New NE B (South) – West to East

26º 13.481'N, 79º 57.775'W to 26º 13.842'N, 79º 55.338'W; depth range 813-881 ft.
Flat textured sediment (worm tubes) with some bioturbation (mounds, depressions) alternating with raised rippled sand waves; ripples decline at 871 ft. Dominant macrofauna consists of *C. briareus* and galatheids with some ophiuroids. Two small isolated rocks (~15 and 30 cm) were observed with hydroids in one case and an anemone in another. The first cidaroid appeared in 867 ft.

26º 13.842'N, 79º 55.338'W to 26º 13.973'N, 79º 54.709'W; depth range 882-887 ft.
Scattered rubble and small rocks (5-30 cm) with hydroids, anemones, cidaroids and a cerianthid. This segment has been mapped as lying along the southernmost extent of the large hatched hard-bottom area in the northeastern corner of the study site. Although this area is categorized as low-cover hard bottom, whereas the two other transect segments that define this area (along EW6 and New NE A (North)) are high-cover hard bottom, the entire area is mapped with a single color because of the complex, patchy distributions of high- and low-cover habitats observed.

26º 13.973'N, 79º 54.709'W to 26º 14.08'N, 79º 54.142'W; 889-945 ft.
Flat sediment with worm-tube turf alternating with elevated areas of obsolete rippled, sparsely bioturbated sediment. A single depression, 13 ft deep, 30-40 ft across, with 20-30º slopes and rubble and debris on the bottom, was observed at 26º 14.032'N, 79º 54.442'W in 930 ft. Dominant organisms include anemones, ophiuroids, cidaroids. Four pennatulids were observed along this segment, one on the depression floor.

13. New NE Tie A-B – South to North

26º 14.161'N, 79º 54.152'W to 26º 14.543'N, 79º 54.126'W; depth range 928-932 ft.
Flat sediment with worm-tube turf alternating with elevated areas of obsolete rippled sparsely bioturbated sediment. Organisms include anemones, ophiuroids, asteroids, cidaroids, galatheids and a cerianthid.

26º 14.543'N, 79º 54.126'W to 26º 14.747'N, 79º 54.137'W; depth range 934-925 ft.
Series of at least several large depressions with maximum vertical relief of 11 ft with 20-30º slopes (diameters not recorded). The floors of some of these features exhibit what appears to be white consolidated clayey substrates that might also include recently exposed limestone. The field description refers to this area as rife with what appear to be karst topographic features and low- to moderate-relief sediment dunes. Organisms include anemones, cidaroids, asteroids and ophiuroids. Three widely separated pennatulids were also observed (26º 14.611'N, 79º 54.133'W to 26º 14.718'N, 79º 54.136'W).

26º 14.747'N, 79º 54.137'W to 26º 14.966'N, 79º 54.143'W; depth range 927-917 ft.
Raised rippled sand waves alternate with flat sediment. Organisms include cidaroids, ophiuroids and anemones. It was noted that the ship was having difficulty running along the transect backward with its bow facing into current, which caused slight deviations in course.

26º 14.966'N, 79º 54.143'W to 26º 14.992'N, 79º 54.140'W; depth range 917-905 ft.
Isolated clusters of largely barren small rocks to 30 cm across, or single small rocks in rippled or flat turfy sediment. Dominant organisms were anemones and cidaroids with one to a few octocorals (Isididae, Nephtheidae, Paramuriceidae).

26º 14.992'N, 79º 54.140'W to 26º 15.765'N, 79º 54.130'W; depth range 900-885 ft.

Rubble, rocks (10-30 cm), low-relief irregular outcrops, 1-2-ft slabs and veneered pavement to 50% cover of field of view, alternating with more scattered rocks and fields of 5-10-cm rubble and sometimes wide expanses of sediment. Hard-bottom organisms include hexactinellid sponges (e.g., *Aphrocallistes* sp.), demosponges (e.g., *Phakellia* sp., Pachastrellidae, Geodiidae), anemones, hydroids, octocorals (?*C. nigra*, unidentified gorgonians and sometimes numerous Isididae), antipatharians, and numerous echiurans. Organisms on sediment substrates include cidaroids and a few pennatulids.

14. New NE A (North) – East to West

26º 15.765'N, 79º 54.130'W to 26º 15.741'N, 79º 54.227'W; depth range 887-883 ft.
A field of scattered rubble and chiefly small low rocks and low-relief outcrops to 20-30 cm across with a few larger rocks to 0.5 m across and low-relief outcrops or pavements to ~1 m across. Organisms include rather sparse sponges (*Aphrocallistes* sp., *Phakellia* sp.), anemones, zoanthids, isidid octocorals, antipatharians and echiurans. Cidaroids are also present.

26º 15.741'N, 79º 54.227'W to 26º 15.723'N, 79º 54.282'W; 880-881 ft.
Flat or obsolete rippled sediment with no hard substrate. An antipatharian was recorded in the field notes but was not visible on the main camera, and there was no audio track.

26º 15.723'N, 79º 54.282'W, 26º 15.706'N, 79º 54.397'W; 878-876 ft.
Fields of sparse to abundant rubble chiefly <10 cm across, with occasional areas of larger rocks and low-relief slabs and outcrops to 0.75 m across. Dominant hard-bottom organisms are anemones and ?*C. nigra*, with sparse *Aphrocallistes* sp. and other hexactinellids, demosponges (Geodiidae), Isididae, antipatharians, echiurans and cidaroids.

26º 15.706'N, 79º 54.397'W to 26º 15.722'N, 79º 54.399'W
Ship standing by; a short gap exists between the end of the last segment and the beginning of the next.

26º 15.722'N, 79º 54.399'W to 26º 15.269'N, 79º 56.615'W; depth range 869-806 ft.
Large boulders, slabs, pavement, boulder field with smaller rocks (10-50 cm across), mixed with fields of sparse to abundant rubble. This area rises from a depth of 869 ft in the east to a minimum of 806 ft before sloping down again to 835 ft to the west. Hard-bottom organisms include hexactinellid sponges (e.g., *Aphrocallistes* sp.), demosponges (e.g., *Phakellia* sp., Pachastrellidae, Geodiidae), anemones, octocorals (e.g., ?*C. nigra*, Isididae and unidentified gorgonians), numerous antipatharians, echiurans and cidaroids.

26º 15.269'N, 79º 56.615'W to 26º 15.240'N, 79º 54.742'W; depth range 836-847 ft.
Isolated small rocks, scattered clusters of small rocks, a few up to 0.4 m, with an occasional veneered slab to 1 m across, and a field of rubble, on rippled sediment with some expanses of open sediment. Hard-bottom organisms include hexactinellids, anemones, Isididae, antipatharians; soft-bottom organisms include cidaroids, asteroids, ?*Actinauge longicornis* and *Coronaster briareus*.

26º 15.240'N, 79º 56.742'W to 26º 15.190'N, 79º 56.989'W; depth range 847-842 ft.
A series of large sand waves with 3-8-ft vertical relief, covered with obsolete ripples and interspersed with flat sediment areas with worm tubes. Some rocks 10-30 cm across were observed at the base of one sediment slope. Organisms are chiefly *C. briareus* and another asteroid (?*Sclerasterias* sp.) and cidaroids, with some ?*A. longicornis*. A single tilefish burrow was observed in 845 ft (26º 15.224'N, 79º 56.855'W).

26º 15.190'N, 79º 56.989'W to 26º 15.173'N, 79º 57.113'W; 845-842 ft.

Obsolete rippled sediment with an asteroid, small anemone and *C. briareus.*

26º 15.173'N, 79º 57.113'W to 26º 15.156'N, 79º 56.226'W; 840-836 ft.
Obsolete rippled sediment with widely scattered variously sized rocks to 1-m across, occasionally in loose clusters. Hard-bottom organisms include anemones, hormathiid anemones, nephtheids, hydroids, possible antipatharians. Organisms on sediment include *C. briareus*, anemones and galatheids.

26º 15.156'N, 79º 56.226'W to 26º 15.047'N, 79º 57.778'W; depth range 838-809 ft.
Rippled and sparsely bioturbated sediment, passing to rippled sand waves alternating with narrow strips of flat bioturbated sediment; a single flat rock was observed, as was a 7-ft deep depression in 829 ft (26º 15.071'N, 79º 56.630'W). Dominant organisms are *C. briareus* and other asteroids, galatheids and ?*A. longicornis*.

15. New N-S – North to South
26º 15.047'N, 79º 57.778'W to 26º 11.620'N, 79º 57.850'W; depth range 809-831 ft.
Chiefly low sand waves with obsolete rippled sediment alternating with flat bioturbated sediment with small mounds, small tubes and tufts. A few widely isolated small rocks or flat white outcrops to 1-m across. Some hard bottoms have anemones and hydroids. Soft bottom organisms include *C. briareus*, ?*Sclerasterias* sp., ?*A. longicornis*, galatheids and cerianthids. A fishing boat wreck was seen at 26º 13.740'N, 79º 57.851'W.

D. Quantitative Analyses – Percent cover by habitat (CPC Analysis)

Table 4 gives locations and times of quantitative still photographic series and image numbers exposed in each. Latitudes and longitudes indicate points at which each series began. Table YY gives numbers of frames and total numbers of points analyzed, and percentages of substrate types and major faunal groups per transect.

Table 4. Locations and times of quantitative still photographic series and numbers of images exposed in each. Latitudes and longitudes indicate points at which transects began.

Site no.	Transect	LatDM	LonDM	LatDD	LonDD	Image numbers	Date	Time
1	EW 6	26 14.448	79 55.787	26.24080000	-79.92978333	1610-1722	15-Apr-06	1546-1613
2	EW 4	26 11.801	79 57.360	26.19668333	-79.95600000	1814-1949	16-Apr-06	0703-0745
3	EW 3	26 10.544	79 54.508	26.17573333	-79.90846667	2045-2143	16-Apr-06	1322-1340
4	EW 3	26 10.414	79 57.148	26.17356667	-79.95246667	2144-2241	16-Apr-06	1340-1400
5	EW 2	26 09.243	79 58.035	26.15405000	-79.96725000	2330-2411	17-Apr-06	0200-0222
6	EW 2	26 09.978	79 54.193	26.16630000	-79.90321667	2412-2533	17-Apr-06	0354-0420
7	EW 2	26 09.766	79 55.985	26.16276667	-79.93308333	2538-2654	17-Apr-06	0516-0641
8	NE A-B Tie	26 14.992	79 54.140	26.24988333	-79.90233333	2771-2873	17-Apr-06	1948-2013

A total of 869 still images were analyzed at the eight sites, with 82-136 per site (mean of 108.6 images per series). Coral Point Count (CPC)© software was used to code 50 points in each image. As indicated in the methodology section, we analyzed organism abundances and densities in detail separately by counting all organisms 3-4 cm or larger per image (described below). Slight differences between expected and actual numbers of points for each series (e.g., 5649 points instead of 5650 at site 1 [113 images x 50 points per image]) were due to a few non-data points (shadows). Figure 12 illustrates percentage cover by

photographic series (excluding photo effects such as reflections or glare, which accounted for no more than 0.06% of image area per site). No hard substrates derived from deep-sea corals were observed (e.g., coral rubble, dead standing or live coral). Soft substrates include obsolete rippled and flat bioturbated sediments. Hard substrates accounted for 17.10 to 95.32% of cover in the eight sites selected because of their high biological interest. Sites 1, 4, 5 and 6 were coded from field notes and video as chiefly high-cover hard bottom habitat, while sites 2, 3, 7 and 8 were coded as mixtures of high- and low-cover. However, analysis of quantitative still photographs indicates that sediment substrates account for 55-82% of bottom cover at sites 1-4, while hard substrates account for 58-95% of bottom cover at sites 5-8 (Table 5, Figure 12). The apparent discrepancy between video coding and quantitative still image analysis is due to the high variability and patchiness of exposed hard substrates at these sites. Extensive areas of hard bottom were frequently described as being separated by expanses of sediment—areas ranging from a few to over 10 m across. Habitats were also coded from video as high-cover if they supported substantial numbers or diversity of sessile macrofauna, particularly those contributing to complex 3-dimensional habitat (i.e., larger sponges, isidid and primnoid octocorals), regardless of the extent of exposed hard bottom. Only a very few observations were made of sediment-veneered hard bottom, that is, sediment substrates that betrayed the presence of buried hard bottom by the growth of sessile attached macrofauna (e.g., sponges, octocorals), and these fell within habitats otherwise described as hard bottom. Benthic macrofaunal organisms accounted for about 1-9% of cover, with anthozoans (0.71-4.09%) responsible for the most cover at all sites (though tied with echinoderms at site 2), followed by echinoderms, echiurans, hydrozoans and sponges (0.02-1.73%).

Table 5. CPC analysis of percentage substrate cover. Numbers of frames and total numbers of points analyzed, and percentages of substrate types and major faunal groups per photo series. All organisms were summed for graphic display in Figure 12 below. Figures in boldface highlight cells with non-zero values. Debris refers to non-indigenous materials, either natural or artificial (e.g., mats of *Sargassum* weed, plastic, aluminum cans, fishing line).

Site number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Transect number	**EW 6**	**EW 4**	**EW 3**	**EW 3**	**EW 2**	**EW 2**	**EW 2**	**NE A-B Tie**
Number of frames	113	136	99	97	82	122	117	103
Total points	5649	6797	4949	4741	4098	5998	5798	5149
MAJOR CATEGORY (%)								
SOFT SUBSTRATE	**81.73**	**64.60**	**79.32**	**54.94**	**37.93**	**3.29**	**0.02**	**3.52**
HARD SUBSTRATE	**17.10**	**32.23**	**19.59**	**40.90**	**58.28**	**94.36**	**95.32**	**87.11**
DEBRIS	**0.11**	**0.37**	**0.02**	**0.53**	**1.17**	**0.15**	**0.79**	**0.31**
PORIFERA	**0.07**	**0.33**	**0.04**	**0.62**	**0.15**	**0.20**	**0.26**	**0.64**
ANTHOZOA	**0.79**	**0.80**	**0.71**	**1.51**	**1.29**	**1.47**	**1.59**	**4.09**
HYDROZOA	**0.02**	**0.07**	**0.04**	**0.21**	**0.29**	**0.20**	**0.85**	**0.78**
ECHINODERMATA	**0.13**	**0.80**	**0.10**	**0.40**	**0.10**	**0.05**	**0.09**	**1.73**
ECHIURA	**0.05**	**0.25**	**0.10**	**0.47**	**0.68**	**0.20**	**0.86**	**1.40**
CRUSTACEA	0.00	**0.01**	0.00	0.00	0.00	0.00	**0.07**	**0.04**
CHORDATA	0.00	**0.07**	**0.02**	**0.04**	**0.05**	**0.02**	**0.05**	**0.14**
UROCHORDATA	0.00	**0.01**	0.00	0.00	0.00	0.00	0.00	0.00
MOLLUSCA	0.00	0.00	0.00	**0.02**	0.00	0.00	0.00	**0.04**
ANNELIDA	0.00	**0.37**	0.00	**0.11**	0.00	0.00	**0.02**	0.00
UNIDENTIFIED	0.00	**0.06**	0.00	**0.21**	**0.05**	**0.07**	**0.09**	**0.14**
PHOTO EFFECT	0.00	0.00	**0.06**	**0.04**	0.00	0.00	0.00	**0.06**
[ORGANISMS TOTAL]	1.06	2.80	1.01	3.59	2.61	2.20	3.87	9.00
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

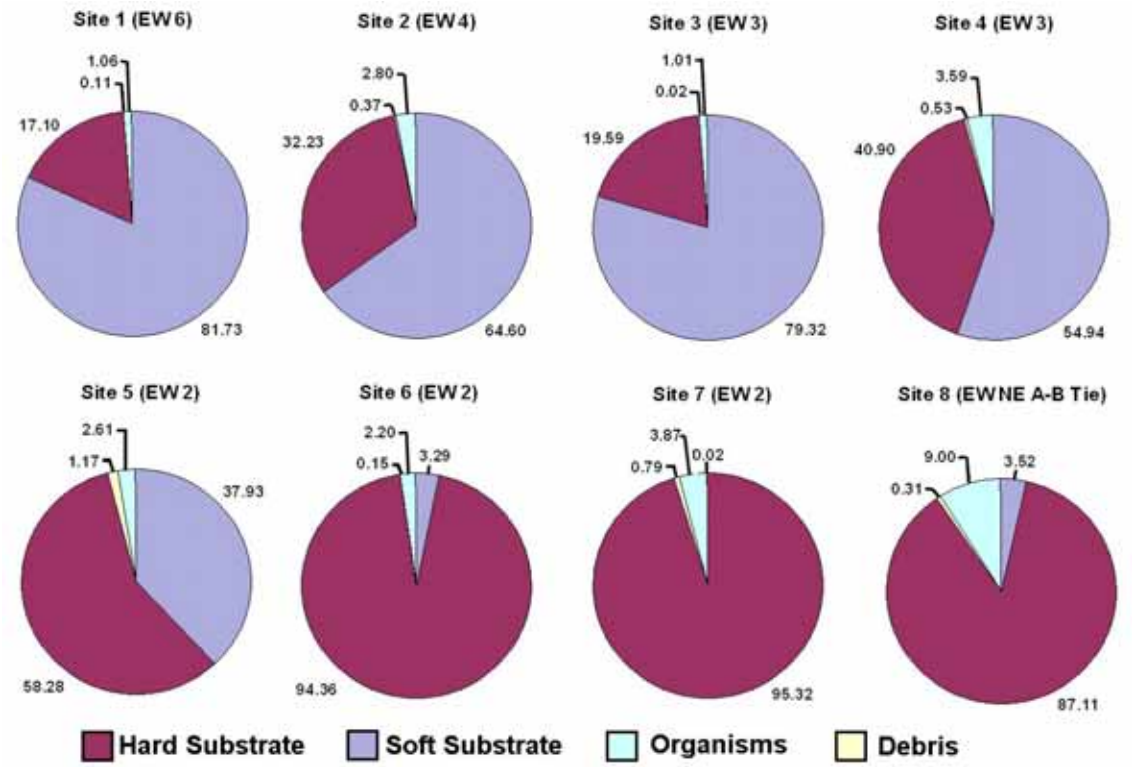

Figure 12. CPC analysis of percentage substrate cover. Percentage cover by photographic series excluding photo effects (e.g., reflections, glare), which accounted for no more than 0.06% of image area per site. The hard substrate category includes all forms of exposed limestone—rubble, larger rocks, solid outcrops and pavements.

E. Quantitative Analyses – Benthic Macrofaunal Abundance and Density

Table 6 ranks the most abundant groups at each site in order of decreasing density (individuals m^{-2}) using the densities of all organisms larger than ~3-4 cm in the 869 photographic images analyzed by CPC software for percent cover in the previous section. Sea anemones (Actiniaria) were the most abundant organisms per unit area in 5 of the 8 photo series, and ranked either second or third to zoanthids or echiurans at the other two. Echiurans ranked first twice and second three times; nephtheids (?*Capnella nigra*) ranked second once and third at four sites, and all sponges combined (the sum of hexactinellid, unidentified demosponge, *Phakellia* sp., pachastrellid and geodiid densities) ranked third at 2 sites and fourth at 5 others. Zoanthids occurred at high densities and in substantial numbers only at sites 1, 6 and 8. These ranks were extracted from densities in Tables 7-9 below. Table 7 gives counts, densities and percents of total density; Tables 8 and 9 break down these totals by sessile (e.g., sponges, octocorals) and semi-sessile (e.g., anemones, echiurans, crinoids) versus mobile organisms (e.g., echinoids, fishes), respectively. The separation recognizes the division between organisms that produce habitat (Table 7) and those that occupy it (Table 8). Though not cemented or attached to hard substrates, echiuran worms and cerianthid (burrowing) anemones have been included here (the former as mobile and the latter as semi-sessile) because both occur in association with hard substrates, perhaps using buried crevices as retreats (though some cerianthids also occur in sediments not associated with hard substrates). In cases in which smaller (~2 cm) specimens of typically larger sessile or semi-sessile taxa were easily recognizable (e.g.,

?*Capnella nigra*), they have also been included. The area covered at each site ranged from 52.12 to 182.04 m^2.

Table 6. Ranking of dominant groups by density at each of the eight still photographic sites. *Zoanthids had the same density as holothuroids at site 4. **Zoanthid densities ranked behind those of gorgonians and cerianthids at sites 5 and 7.

	1	2	3	4	5	6	7	8
Actiniaria	2	1	2	1	1	1	1	3
Echiura	5	4	1	2	2	3	2	1
Nephtheidae	4	2	3	3	3	5	3	4
Total Porifera	3	3	4	4	4	4	4	5
Zoanthidea	1	5	5	5*	7**	2	7**	2

Total organism densities (Table 7) exhibited a moderate range of variation, from 3.85 and 4.84 organisms m^{-2} at sites 6 and 5, respectively, through 5.36 (site 2), 5.48 (site 1), 6.24 (site 7) and 6.65 m^{-2} (site 4), to 10.23 (site 8) and 10.80 m^{-2} (site 3). However, total densities for sessile and semi-sessile habitat-forming groups (Table 8) ranged only from 3.15 (site 6) to 6.49 m^{-2} (site 8). These figures do not include hydroids, which could not be accurately counted in many cases due to their thin morphology, and solitary corals, most of which were <2 cm across and often could not be identified as living versus dead.

Maximum densities for the dominant groups were as follows: echiurans (3.32 m^{-2}, site 8), zoanthids (2.86 m^{-2}, site 8), sea anemones (1.90 m^{-2}, site 4), nephtheids (1.22 m^{-2}, site 2), and total sponges (0.71 m^{-2}, site 1). No other group occurred at densities greater than 0.5 m^{-2}. Organisms classified as corals in the broad sense and often producing complex 3-dimensional hard-bottom habitats contributed at most 0.48 (gorgonians) and 0.45 colonies m^{-2} (stylasterids), both at site 8. Elsewhere, these groups occurred at substantially lower densities: 0.08-0.27 m^{-2} for gorgonians, 0.06-0.17 m^{-2} for stylasterids. Maxima per frame were 20 nephtheids, 17 anemones, 9 zoanthids, 6 hexactinellids, 6 gorgonians (Isididae), and 19 demosponges, each in separate images. The latter was an unusual case of numerous tiny individuals; the frame with the second largest number of sponges had 10, and the great majority had fewer than 5, when any were present. The majority of hard-bottom images had no more than 1 or 2 of any group with few exceptions, e.g., most frames at site 8 included ≥3 zoanthid colonies.

Figure 13 shows the contributions of major taxonomic groups of sessile and semi-sessile, habitat-forming hard-bottom organisms (i.e., sponges and cnidarians) to the total density of these groups alone at each of the quantitative still photographic sites. Zoanthids dominate sites 1 (EW6, 39.92%) and 8 (NE Tie A-B, 46.65%), on the two northernmost transects, while sea anemones (Actiniaria) dominate the remaining sites (39.39-45.95%). Sponges (Porifera) contribute a relatively consistent proportion at all sites—9.74-16.12%--while nephtheid soft corals vary somewhat more—11.24-28.23%. Gorgonians (chiefly Isididae with some Primnoidae and a few unidentified colonies) contribute no more than 7.78%.

Table 7. Counts and densities of individual organisms in CPC analysis images. Most individually recognizable taxa have been grouped by higher taxonomic grouping (e.g., Primnoidae and Isididae together under gorgonians). No. Sp. = number of specimens. Densities (D) were calculated as numbers of a taxonomic group in the total area of the photo series. % = percent contribution of each group to the total density of the site.

	SITE 1 (EW 6) Images 1610-1722			SITE 2 (EW 4) Images 1814-1929			SITE 3 (EW 3) Images 2045-2143			SITE 4 (EW 3) Images 2144-2241			SITE 5 (EW 2) Images 2330-2411			SITE 6 (EW 2) Images 2412-2533			SITE 7 (EW 2) Images 2538-2654			SITE 8 (NE A-B Tie) Images 2771-2873		
		D			D			D			D			D			D			D			D	
TAXON	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**
PORIFERA																								
Hexactinellida	70	0.59	10.74	28	0.19	3.59	17	0.24	4.11	3	0.06	0.86	15	0.12	2.41	25	0.14	3.57	27	0.16	2.64	61	0.45	4.38
Unid. Demospongiae	12	0.10	1.84	29	0.20	3.72	5	0.07	1.21	23	0.44	6.59	35	0.27	5.62	25	0.14	3.57	31	0.19	3.03	23	0.17	1.65
Phakellia sp.	2	0.02	0.31	14	0.10	1.80	2	0.03	0.48	2	0.04	0.57	2	0.02	0.32	17	0.09	2.43	3	0.02	0.29	4	0.03	0.29
Lithistids	0	0.00	0.00	6	0.04	0.77	0	0.00	0.00	3	0.06	0.86	0	0.00	0.00	0	0.00	0.29	0	0.00	0.00	0	0.00	0.00
Pachastrellidae	0	0.00	0.00	3	0.02	0.39	1	0.01	0.24	4	0.08	1.15	0	0.00	0.00	2	0.01	0.00	6	0.04	0.59	3	0.02	0.22
Geodiidae	0	0.00	0.00	0	0.00	0.00	3	0.04	0.72	1	0.02	0.29	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	0.01	0.14
CNIDARIA																								
Gorgonians	10	0.08	1.53	26	0.18	3.34	12	0.17	2.90	10	0.19	2.87	33	0.26	5.30	36	0.20	5.14	45	0.27	4.40	65	0.48	4.66
Nephtheidae	68	0.57	10.43	177	1.22	22.72	71	1.01	17.15	56	1.07	16.05	107	0.83	17.17	64	0.35	9.14	180	1.10	17.61	94	0.69	6.74
Pennatulacea	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.02	0.29	0	0.00	0.00	6	0.03	0.86	0	0.00	0.00	0	0.00	0.00
Actiniaria	94	0.79	14.42	275	1.89	35.30	103	1.46	24.88	99	1.90	28.37	199	1.55	31.94	261	1.43	37.29	271	1.66	26.52	96	0.70	6.89
Antipatharia	0	0.00	0.00	0	0.00	0.00	1	0.01	0.24	0	0.00	0.00	1	0.01	0.16	2	0.01	0.29	0	0.00	0.00	0	0.00	0.00
Zoanthidea	208	1.75	31.90	46	0.32	5.91	15	0.21	3.62	11	0.21	3.15	21	0.16	3.37	101	0.55	14.43	41	0.25	4.01	390	2.86	27.98
Ceriantharia	44	0.37	6.75	2	0.01	0.26	11	0.16	2.66	3	0.06	0.86	25	0.19	4.01	4	0.02	0.57	62	0.38	6.07	36	0.26	2.58
Stylasteridae	13	0.11	1.99	21	0.14	2.70	12	0.17	2.90	9	0.17	2.58	8	0.06	1.28	25	0.14	3.57	22	0.13	2.15	62	0.45	4.45
ECHINODERMATA																								
Asteroidea	2	0.02	0.31	3	0.02	0.39	3	0.04	0.72	6	0.12	1.72	5	0.04	0.80	2	0.01	0.29	6	0.04	0.59	3	0.02	0.22
Echinoidea	20	0.17	3.07	8	0.06	1.03	5	0.07	1.21	3	0.06	0.86	11	0.09	1.77	19	0.10	2.71	10	0.06	0.98	18	0.13	1.29
Holothuroidea	9	0.08	1.38	17	0.12	2.18	13	0.18	3.14	11	0.21	3.15	1	0.01	0.16	3	0.02	0.43	11	0.07	1.08	17	0.12	1.22
Crinoidea	4	0.03	0.61	6	0.04	0.77	0	0.00	0.00	0	0.00	0.00	2	0.02	0.32	1	0.01	0.14	8	0.05	0.78	6	0.04	0.43
ECHIURA																								
Echiura	46	0.39	7.06	79	0.54	10.14	121	1.72	29.23	91	1.75	26.07	141	1.10	22.63	80	0.44	11.43	259	1.58	25.34	453	3.32	32.50
CRUSTACEA																								
Galatheoidea	2	0.02	0.31	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	3	0.02	0.29	2	0.01	0.14
Paguroidea	12	0.10	1.84	5	0.03	0.64	3	0.04	0.72	0	0.00	0.00	2	0.02	0.32	2	0.01	0.29	2	0.01	0.20	17	0.12	1.22
Brachyura	1	0.01	0.15	3	0.02	0.39	1	0.01	0.24	0	0.00	0.00	0	0.00	0.00	1	0.01	0.14	3	0.02	0.29	0	0.00	0.00
Caridea	1	0.01	0.15	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
ANNELIDA																								
Polychaeta	25	0.21	3.83	6	0.04	0.77	4	0.06	0.97	2	0.04	0.57	5	0.04	0.80	2	0.01	0.29	2	0.01	0.20	26	0.19	1.87
MOLLUSCA																								
Gastropoda	3	0.03	0.46	1	0.01	0.13	2	0.03	0.48	6	0.12	1.72	0	0.00	0.00	2	0.01	0.29	3	0.02	0.29	0	0.00	0.00
Polyplacophora	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.02	0.29	0	0.00	0.00	3	0.02	0.43	2	0.01	0.20	4	0.03	0.29
CHORDATA																								
Laemonema	3	0.03	0.46	17	0.12	2.18	5	0.07	1.21	2	0.04	0.57	7	0.05	1.12	15	0.08	2.14	21	0.13	2.05	6	0.04	0.43
Scorpaenidae	0	0.00	0.00	5	0.03	0.64	2	0.03	0.48	1	0.02	0.29	3	0.02	0.48	2	0.01	0.29	4	0.02	0.39	3	0.02	0.22
Paralichthyidae	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Rajiformes	1	0.01	0.15	0	0.00	0.00	2	0.03	0.48	1	0.02	0.29	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.01	0.07
Other fish	2	0.02	0.31	2	0.01	0.26	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	0.01	0.14
TOTAL	**652**	**5.48**	**100.00**	**779**	**5.36**	**100.00**	**414**	**5.87**	**100.00**	**349**	**6.70**	**100.00**	**623**	**4.84**	**100.00**	**700**	**3.85**	**100.00**	**1022**	**6.24**	**100.00**	**1394**	**10.23**	**100.00**
TOTAL AREA (m^2)	**118.99**			**145.25**			**70.48**			**52.12**			**128.71**			**182.04**			**163.66**			**136.28**		

Table 8. Counts and densities of individual sessile and semisessile organisms in CPC analysis images. Holothuroids are suspension-feeding psolids. Polychaetes are sessile tube-dwellers (e.g., Sabellidae). See Table 7 above for explanation of taxonomy and abbreviations.

	SITE 1 (EW 6) Images 1610-1722			SITE 2 (EW 4) Images 1814-1929			SITE 3 (EW 3) Images 2045-2143			SITE 4 (EW 3) Images 2144-2241			SITE 5 (EW 2) Images 2330-2411			SITE 6 (EW 2) Images 2412-2533			SITE 7 (EW 2) Images 2538-2654			SITE 8 (NE A-B Tie) Images 2771-2873		
		D			D			D			D			D			D			D			D	
TAXON	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**
PORIFERA																								
Hexactinellida	70	0.59	12.52	28	0.19	4.27	17	0.24	6.30	3	0.06	1.26	15	0.12	3.30	25	0.14	4.36	27	0.16	3.81	61	0.45	6.89
Unid. Demospongiae	12	0.10	2.15	29	0.20	4.42	5	0.07	1.85	23	0.44	9.66	35	0.27	7.71	25	0.14	4.36	31	0.19	4.37	23	0.17	2.60
Phakellia sp.	2	0.02	0.36	14	0.10	2.13	2	0.03	0.74	2	0.04	0.84	2	0.02	0.44	17	0.09	2.96	3	0.02	0.42	4	0.03	0.45
Lithistida	0	0.00	0.00	6	0.04	0.91	0	0.00	0.00	3	0.06	1.26	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Pachastrellidae	0	0.00	0.00	3	0.02	0.46	1	0.01	0.37	4	0.08	1.68	0	0.00	0.00	2	0.01	0.35	6	0.04	0.85	3	0.02	0.34
Geodiidae	0	0.00	0.00	0	0.00	0.00	3	0.04	1.11	1	0.02	0.42	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	0.01	0.23
CNIDARIA																								
Gorgonians	10	0.08	1.79	26	0.18	3.96	12	0.17	4.44	10	0.19	4.20	33	0.26	7.27	36	0.20	6.27	45	0.27	6.35	65	0.48	7.34
Nephtheidae	68	0.57	12.16	177	1.22	26.98	71	1.01	26.30	56	1.07	23.53	107	0.83	23.57	64	0.35	11.15	180	1.10	25.39	94	0.69	10.62
Pennatulacea	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.02	0.42	0	0.00	0.00	6	0.03	1.05	0	0.00	0.00	0	0.00	0.00
Actiniaria	94	0.79	16.82	275	1.89	41.92	103	1.46	38.15	99	1.90	41.60	199	1.55	43.83	261	1.43	45.47	271	1.66	38.22	96	0.70	10.85
Antipatharia	0	0.00	0.00	0	0.00	0.00	1	0.01	0.37	0	0.00	0.00	1	0.01	0.22	2	0.01	0.35	0	0.00	0.00	0	0.00	0.00
Zoanthidea	208	1.75	37.21	46	0.32	7.01	15	0.21	5.56	11	0.21	4.62	21	0.16	4.63	101	0.55	17.60	41	0.25	5.78	390	2.86	44.07
Ceriantharia	44	0.37	7.87	2	0.01	0.30	11	0.16	4.07	3	0.06	1.26	25	0.19	5.51	4	0.02	0.70	62	0.38	8.74	36	0.26	4.07
Stylasteridae	13	0.11	2.33	21	0.14	3.20	12	0.17	4.44	9	0.17	3.78	8	0.06	1.76	25	0.14	4.36	22	0.13	3.10	62	0.45	7.01
ECHINODERMATA																								
Holothuroidea	9	0.08	1.61	17	0.12	2.59	13	0.18	4.81	11	0.21	4.62	1	0.01	0.22	3	0.02	0.52	11	0.07	1.55	17	0.12	1.92
Crinoidea	4	0.03	0.72	6	0.04	0.91	0	0.00	0.00	0	0.00	0.00	2	0.02	0.44	1	0.01	0.17	8	0.05	1.13	6	0.04	0.68
ANNELIDA																								
Polychaeta	25	0.21	4.47	6	0.04	0.91	4	0.06	1.48	2	0.04	0.84	5	0.04	1.10	2	0.01	0.35	2	0.01	0.28	26	0.19	2.94
TOTAL	**559**	**4.70**	**100.00**	**656**	**4.52**	**100.00**	**270**	**3.83**	**100.00**	**238**	**4.57**	**100.00**	**454**	**3.53**	**100.00**	**574**	**3.15**	**100.00**	**709**	**4.33**	**100.00**	**885**	**6.49**	**100.00**
TOTAL AREA (m^2)	**118.99**			**145.25**			**70.48**			**52.12**			**128.71**			**182.04**			**163.66**			**136.28**		

Table 9. Counts and densities of individual mobile organisms in CPC analysis images. See Table 7 above for explanation of taxonomy and abbreviations.

	SITE 1 (EW 6) Images 1610-1722			SITE 2 (EW 4) Images 1814-1929			SITE 3 (EW 3) Images 2045-2143			SITE 4 (EW 3) Images 2144-2241			SITE 5 (EW 2) Images 2330-2411			SITE 6 (EW 2) Images 2412-2533			SITE 7 (EW 2) Images 2538-2654			SITE 8 (NE A-B Tie) Images 2771-2873		
		D			D			D			D			D			D			D			D	
TAXON	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**	**No. Sp.**	**(m^{-2})**	**%**
ECHINODERMATA																								
Asteroidea	2	0.02	2.15	3	0.02	2.44	3	0.04	2.08	6	0.12	5.41	5	0.04	2.96	2	0.01	1.59	6	0.04	1.92	3	0.02	0.59
Echinoidea	20	0.17	21.51	8	0.06	6.50	5	0.07	3.47	3	0.06	2.70	11	0.09	6.51	19	0.10	15.08	10	0.06	3.19	18	0.13	3.54
CRUSTACEA																								
Galatheoidea	2	0.02	2.15	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	3	0.02	0.96	2	0.01	0.39
Paguroidea	12	0.10	12.90	5	0.03	4.07	3	0.04	2.08	0	0.00	0.00	2	0.02	1.18	2	0.01	1.59	2	0.01	0.64	17	0.12	3.34
Brachyura	1	0.01	1.08	3	0.02	2.44	1	0.01	0.69	0	0.00	0.00	0	0.00	0.00	1	0.01	0.79	3	0.02	0.96	0	0.00	0.00
Caridea	1	0.01	1.08	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
ECHIURA																								
Echiura	46	0.39	49.46	79	0.54	64.23	121	1.72	84.03	91	1.75	81.98	141	1.10	83.43	80	0.44	63.49	259	1.58	82.75	453	3.32	89.00
MOLLUSCA																								
Gastropoda	3	0.03	3.23	1	0.01	0.81	2	0.03	1.39	6	0.12	5.41	0	0.00	0.00	2	0.01	1.59	3	0.02	0.96	0	0.00	0.00
Polyplacophora	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.02	0.90	0	0.00	0.00	3	0.02	2.38	2	0.01	0.64	4	0.03	0.79
CHORDATA																								
Laemonema	3	0.03	3.23	17	0.12	13.82	5	0.07	3.47	2	0.04	1.80	7	0.05	4.14	15	0.08	11.90	21	0.13	6.71	6	0.04	1.18
Scorpaenidae	0	0.00	0.00	5	0.03	4.07	2	0.03	1.39	1	0.02	0.90	3	0.02	1.78	2	0.01	1.59	4	0.02	1.28	3	0.02	0.59
Paralichthyidae	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Rajiformes	1	0.01	1.08	0	0.00	0.00	2	0.03	1.39	1	0.02	0.90	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.01	0.20
Other fish	2	0.02	2.15	2	0.01	1.63	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	0.01	0.39
TOTAL	**93**	**0.78**	**100.00**	**123**	**0.85**	**100.00**	**144**	**2.04**	**100.00**	**111**	**2.13**	**100.00**	**169**	**1.31**	**100.00**	**126**	**0.69**	**100.00**	**313**	**1.91**	**100.00**	**509**	**3.74**	**100.00**
TOTAL AREA (m^2)	**118.99**			**145.25**			**70.48**			**52.12**			**128.71**			**182.04**			**163.66**			**136.28**		

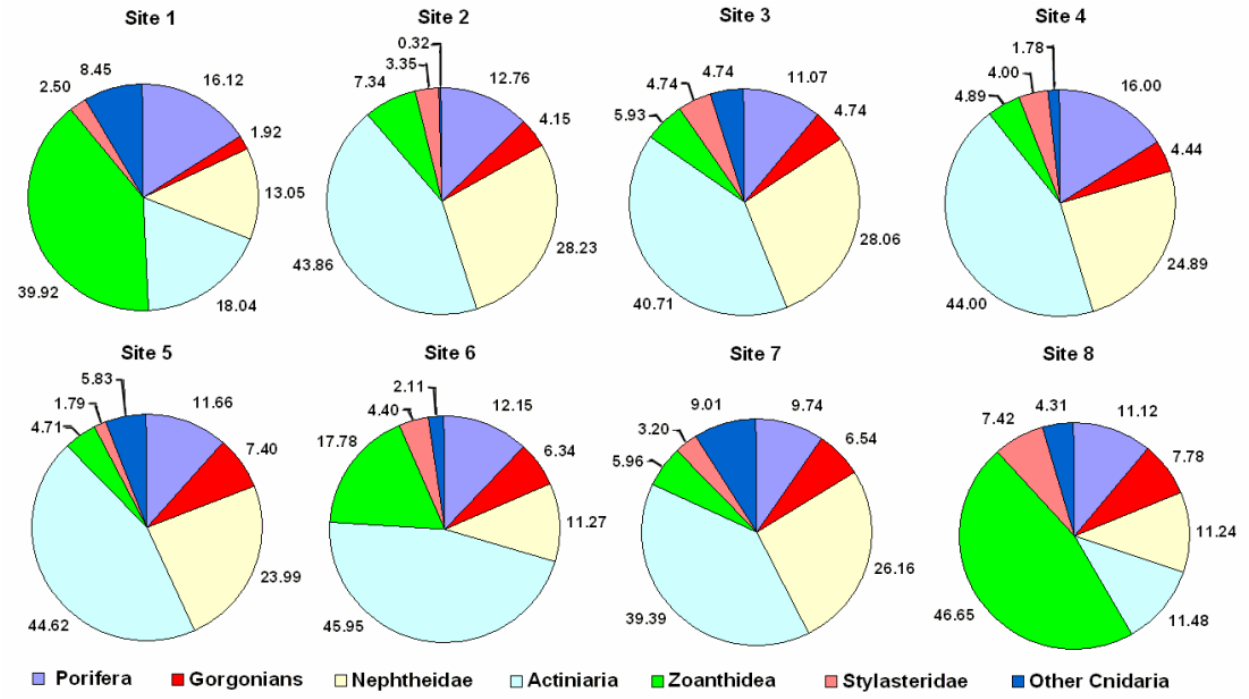

Figure 13. Contributions of major taxonomic groups to the total density of sessile and semi-sessile, habitat-forming, hard-bottom organisms at quantitative still photographic sites. Other cnidarians include antipatharians, pennatulids, cerianthids and stylasterids.

X. POTENTIAL IMPACTS

The FFWCC "Guidelines for Conducting Offshore Benthic Surveys" indicates that reports should "quantify the potential acreage of each substrate and habitat type that would be directly and indirectly impacted by the proposed projects." We have not incorporated such estimates for the following reasons. Calculations of the extent of turbidity clouds and potential burial of hard substrates by construction activities are dependent upon flow velocity and direction at the time of construction and are beyond the scope of work of this project. The areas of hard substrate identified and mapped during this survey consist of complex, irregularly-distributed combinations of high and low hard-cover habitats interspersed with expanses of sediment. Simple use of the geohazards sidescan data mapped as hard substrate will overestimate actual hard-bottom habitat acreage.

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XII. APPENDICES

Appendix 1. List of taxa identified during the benthic video survey. Rare isolated species may not appear in habitat summaries or quantitative analyses.

Appendix 2. DWP benthic habitat map based on a combination of the benthic video survey along transect lines and refined sidescan data from the geohazards survey. Hatched GIS habitat polygons represent interpolations between transect lines north of the geohazards survey area. Arrowhead indicate the direction in which major transects were run. Transect EW6 was split due to sea conditions with the western half run west to east and the eastern half run east to west. [Appendix 2 DeepWaterPortHabitatMap.jpg]

Appendix 3. GIS database summary for habitat map. Latitudes and longitudes indicate beginning position for each habitat description. Points represent isolated observations (e.g., individual pieces of rubble or rock on otherwise sediment bottoms). Colors correspond to habitat lines, areas and polygons in the habitat map above. Rows outlined with heavy black borders represent alterations that will be included in the final version. [APPENDED. Also at Appendix 3 GIS database Summary.xls]

Appendix 4. GIS datafiles. [Appendix 4 DWP GIS Datafiles.zip]

Appendix 5. Benthic video survey ROV transect logs. Abbreviations of names, substrates and habitats have been expanded (e.g., cor to *Coronaster*, ob RS to obsolete rippled sediment). Highlighted cells indicate initial post-cruise habitat designations. Colors parallel those used in the habitat map (tan = low cover hard bottom, gold = high cover hard bottom, light blue = large-scale sediment features, lavender = pennatulids, green = tilefish burrow). Some were modified following review of videotapes. [APPENDED. Also at Appendix 5 ROV field notes all tapes.xls]

Appendix 1. List of taxa identified during the benthic video survey. Rare isolated species may not appear in habitat summaries or quantitative analyses.

Phylum Porifera (sponges)
- Class Hexactinellida (glass sponges)
  - Order Hexactinosida
    - Family Aphrocallistidae
      - *Aphrocallistes* sp.
    - Family Farreidae
      - ?*Farrea* sp.
  - Unidentified hexactinellids
- Class Demospongiae
  - Order Astrophorida
    - Family Geodiidae
      - Unidentified geodiid
    - Family Pachastrellidae
      - Unidentified pachastrellid
  - Order Lithistida
    - Family Corallistidae
      - *Coraliistes* sp.
    - Unidentified lithistids
  - Order Halochondrida
    - Family Axinellidae
      - *Phakellia* sp.
  - Order Haplosclerida
    - Family Petrosiidae
      - Unidentified petrosiid
  - Unidentified demosponges

Phylum Cnidaria
- Subphylum Anthozoa
  - Class Octocorallia (soft corals, gorgonians, sea pens)
    - Order Alcyonacea 14 families
      - Family Isididae (bamboo corals)
        - ?*Isidella* sp.
      - Family Paramuriceidae
        - *Swiftia* sp. (on airplane fuselage)
        - Unidentified paramuriceid
      - Family Primnoidae
        - *Callogorgia americana*
        - ?*Plumarella* sp.
      - Family Nephtheidae
        - ?*Capnella nigra*
    - Order Pennatulacea
      - Unidentified pennatulid
  - Class Hexacorallia (stony corals, anemones, black corals)
    - Order Actiniaria (sea anemones)
      - Family Hormathiidae
        - ?*Actinauge longicornis*
        - Unidentified hormathiid (Venus flytrap)

Anemone sp. 1
Anemone sp. 2
Anemone sp. 3
Anemone sp. 4
Anemone sp. 5
Order Zoanthidea (colonial anemones)
Unidentified zoanthids
Order Ceriantharia
Unidentified cerianthids
Order Antipatharia (black corals)
Family Antipathidae
Stichopathes luetkeni
Unidentified antipatharian(s)
Order Scleractinia (stony corals)
Unidentified solitary corals
Unidentified branching azooxanthellate coral (on airplane fuselage)
Subphylum Medusozoa
Class Hydrozoa
Order Filifera
Family Stylasteridae
Unidentified stylasterid
Unidentified athecate hydroid
Order Leptothecata
Unidentified plumularioid hydroids

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia
Family Trochidae
Calliostoma sp. (shells occupied by hermit crabs)
Family Volutidae
Scaphella sp. (shells occupied by hermit crabs)
Class Polyplacophora
Unidentified chiton
Class Cephalopoda
Order Sepiolida
Family Sepiolidae
Semirossia tenera

Phylum Annelida
Class Polychaeta
"Subclass" Canalipalpata
Family Sabellidae
Unidentified sabellids
Family Serpulidae
Unidentified serpulids

Phylum Echiura
Family ?Bonellidae
Unidentified echiuran

Phylum Arthropoda
- Subphylum Crustacea
  - Order Decapoda
    - Infraorder ?Caridea
      - Unidentified shrimp(s)
    - Infraorder Anomura
      - Family Galatheidae
        - ?*Munida* sp.
      - Family Chyrostylidae
        - ?*Eumunida picta*
      - Family Pylochelidae
        - Unidentified pylochelid
      - Family Paguridae
        - Unidentified pagurid(s)
    - Infraorder Brachyura
      - Family Cancridae
        - *Cancer borealis*
      - Family Portunidae
        - *Bathynectes longispina*
      - Family Pisidae
        - *Rochinia crassa*
      - Unidentified spider crab(s)
      - Unidentified crab(s)

Phylum Echinodermata
- Class Crinoidea
  - Order Comatulidia
    - Family Antedonidae
      - Unidentified antedonid
- Class Asteroidea
  - Order Forcipulata
    - Family Asteriidae
      - *Coronaster briareus*
      - ?*Sclerasterias* sp.
  - Order Paxillosida
    - Family Astropectinidae
      - ?*Astropecten nitidus*
    - Family Goniasteridae
      - Unidentified goniasterid
  - Unidentified asteroids
- Class Ophiuroidea
  - Order Phrynophiurida
    - Family Asteroschematidae
      - Unidentified asteroschematid
  - Order Ophiura
    - Family ?Ophiacanthidae

Unidentified ?ophiacanthid
Family ?Ophiuridae
Unidentified ?ophiurid
Class Echinoidea
Order Cidaroida
Family Cidaridae
?*Cidaris rugosa*
?*Stylocidaris* sp.
Order Echinoida
Family Echinidae
?*Echinus affinis*
Order Echinothurioida
Family Echinothuriidae
?*Araeosoma* sp.
Class Holothuroidea
Order Dendrochirotida
Family Psolidae
Unidentified psolid

Phylum Chordata
Subphylum Vertebrata
Class Chondrichthyes
Order Chimaeriformes
Unidentified chimaera
Order Rajiformes
Family Rajidae
Unidentified rajid
Family Torpedinidae
Benthobatis marcida
Order Carcharhiniformes
Family Scyliorhinidae
Galeus arae
Class Osteichthyes
Order Anguilliformes
Unidentified eel(s)
Order Scorpaeniformes
Family Scorpaenidae
Unidentified scorpaenid(s)
Family Sebastidae
Helicolenus dactylopterus
Order Pleuronectiformes
Family Paralichthyidae
?*Citharichthys arctifrons*
Order Gadiformes
Family Moridae
Laemonema melanurum
Family Phycidae

Unidentified phycid
Order Aulopiformes
Family Chlorophthalmidae
?*Chlorophthalmus agassizi*
Order Perciformes
Family Malacanthidae
Lopholatilus chamaeleonticeps
Caulolatilus ?*microps*
Family Serranidae
?*Epinephelus niveatus*
Unidentified anthiine

APPENDIX 3

Num	LatDM	LonDM	LatDD	LonDD	Transect	Tape No.	Habitat	TIME	DEPTH	POINT SITES	Photo Site	DESCRIPTION	FINAL PHOTO SITES
1	26 13.292	80 1.161	26.22056667	-80.01943333	EW6	1	Sediment	0642	618-651		N	Bioturbated textured sediment; ripples first appear in 667 ft; low ripples alternating with bioturbated sediment; Coronaster, cerianthid, anemone	
15	26 14.42	79 57.987	26.24033333	-79.96645000	EW6	5	Low Cover Hard	1149	800	POINT	N	2 small rubble bits	
16	26 14.448	79 57.905	26.24080000	-79.96508333	EW6	5	Low Cover Hard	1155	804	POINT	N	Cluster of small rocks below edge of sand wave, nephthyids?, Coronaster	
19	26 14.563	79 57.537	26.24271667	-79.95895000	EW6	6	Low Cover Hard	1218	833	POINT	N	1 bit of rubble in depression	
20	26 14.603	79 57.438	26.24338333	-79.95730000	EW6	6	Malacanthid	1225	842	POINT	N	Small flat white outcrop w 1 anemone beyond edge of sand wave, otherwise barren; 0.8-M LONG ?GREAT NORTHERN TILEFISH WITH EXCAVATION	
21	26 14.623	79 57.392	26.24371667	-79.95653333	EW6	6	Low Cover Hard	1228	851	POINT	N	Small area of possible exposed hardbottom to one side in depression between rippled sand waves (possibly sargassum mat); slopes look like consolidated white clay; large fish off camera	
24	26 14.623	79 57.392	26.24371667	-79.95653333	EW6	7	Sediment	1310	853	POINT	N	**First cidaroid urchin**	
26	26 14.436	79 56.558	26.24060000	-79.94263333	EW6	7	Low Cover Hard	1351	860	POINT	N	Tiny rock in depression	
28	26 14.926	79 56.368	26.24876667	-79.93946667	EW6	8	Low Cover Hard	1408	856	POINT	N	Piece of black rubble in rippled sediment	
29	26 14.944	79 56.365	26.24906667	-79.93941667	EW6	8	Low Cover Hard	1408-1412	845-838		N	Scattered rubble, low rocks to 0.6 m almost barren; wide sediment areas; 1 low-relief outcrop to 1.5 m across; chiefly scattered rubble;	
30	26 15.34	79 56.261	26.25566667	-79.93768333	EW6	8	Higher Cover Hard	1413-1419	838-827		1st Photo series	Abundant rubble and small rocks, occas low outcrop to 1.2 m across with some broad areas of empty sediment, few taller rocks (moderate relief); numerous anemones, nephthyids, pachastrellids?, flytrap anemones, few octocorals, Aphrocallistes, hydroids?[too fast]	
	26 15.34	79 56.261			EW6	8	Higher Cover Hard	1413-1419	838-827	POINT		FIRST HEXACTINELLIDS	
31	26 15.142	79 56.151	26.25236667	-79.93585000	EW6	8	Sediment	1419	-		N	**STOP VIDEO TO RETURN TO TRANSECT; DO NOT INCLUDE FROM THIS WAYPOINT TO NEXT IN PLOTTED TRACK STARTING UP AGAIN SOUTH OF TRANSECT LINE**; Obsolete	
32	26 14.030	79 56.225	26.25236667	-79.93585000	EW6	8	Sediment	1521-1536	864-867		N	rippled sediment	
33	26 14.414	79 55.795	26.24023333	-79.92991667	EW6	8	Pennatulid	1535		POINT	N	Sea pen on rippled sediment	
34	26 14.448	79 55.787	26.24080000	-79.92978333	EW6	8	Higher Cover Hard	1536-1554	814-858		2nd Photo series	Begins as chiefly scattered rubble, small rocks & low-relief outcrops to 1. 6 m across, small to large rocks to ~0.3 m high, crowded outcrops & slabs to 1.5 m across, not quite to 0.5 m high (moderate relief) as well as rubble; anemones, flytrap anemones, gorgonians,	**Quant. Photo site 1**

												nephthyids, Isididae, demosponges (incl pachastrellid, geodiid), echiuran, cidaroids	
35	26 14.507	79 55.458	26.24178333	-79.92430000	EW6	8	Sediment	1555	-		N	Empty sediment, off transect	▼
36	26 14.458	79 55.215	26.24096667	-79.92025000	EW6	8	Higher Cover Hard	1604-1611	851-863		3rd Photo series	Low to moderate relief hardbottom, outcrops, slabs & pavement to +1 m across, and rocks; some areas of rippled sediment, moving to chiefly scattered rubble & 1-2-ft rocks with some crowded low-relief hardbottom; Isididae, nephthyids, gorgonians, anemones, flytrap anemone, pachastrellid, Phakellia, glass sponge, Aphrocallistes, echiurans	▼
38	26 14.507	79 54.907	26.24178333	-79.91511667	EW6	9	Sediment	1631-1640	890-896		N	Weakly rippled sediment	
39	26 14.51	79 54.871	26.24183333	-79.91451667	EW6	9	Low Cover Hard	1632-1635	895		N	Widely scattered rubble bits, 30-cm rock; anemones; zoanthids, cidaroids; passing to more abundant rubble 8-10 cm, 5% cover, then just a few cobbles to 30 cm widely separated on sediment; nephthyid	
41	26 14.516	79 54.826	26.24193333	-79.91376667	EW6	9	Sediment	1638-1642	896		N	Rippled or flat sediment with fine tufts	
42	26 14.522	79 54.769	26.24203333	-79.91281667	EW6	9	Higher Cover Hard	1643-1646	894-895		N	Rubble, scattered rocks & more crowded low-relief outcrops, veneered slab to 0. 6 m across, widely scattered rubble 8-15 cm; anemones, nephthyids, gorgonians, primnoid, cidaroids	
43	26 14.524	80 54.735	26.24206667	-80.91225000	EW6	9	Sediment	1646-1654	895-896		N	Rippled sediment alternating with smooth sediment with tubes	
46	26 14.548	79 54.518	26.24246667	-79.90863333	EW6	10	Low Cover Hard	1706	900	POINT	N	Flat sediment with some bioturbation, clusters of worm tubes, raised rippled sand waves; isolated flat 0.5-m boulder	
47	26 14.548	79 54.518	26.24246667	-79.90863333	EW6	10	Low Cover Hard	1708	900		N	Flat sediment; scattered low-relief rocks, outcrops, slab 1-m across; anemones, nephthyids, hydroid?	
48	26 14.552	79 54.494	26.24253333	-79.90823333	EW6	10	Sediment	1709	-		N	Rippled & flat sediment with tubes	
49	26 14.556	79 54.479	26.24260000	-79.90798333	EW6	10	Higher Cover Hard	1709	898	POINT	N	Isolated cluster of low boulders to 0.6 m across, <0.3 m high; nephthyids, anemones	
51	26 14.567	79 54.419	26.24278333	-79.90698333	EW6	10	Low Cover Hard	1713	899	POINT	N	Isolated small flat sediment-veneered outcrop; barren	
	26 14.59	79 54.268			EW6	10	Low Cover Hard			POINT		Small patch of outcrops	
	26 14.59	79 54.268			EW6	10	Pennatulid			POINT		Pennatulid on sediment	
	26 14.59	79 54.268			EW6	10	Sediment	1724	899-910		N	END OF EW6; Flat bioturbated sediment with small tubes alternating with obsolete rippled sediment	
52	26 14.59	79 54.268	26.24316667	-79.90446667	Tie EW5	11	Low Cover Hard	1724-1734	912-928			BEGIN TIE EW5 (ALTERNATE - 1/10 NM WEST OF PLANNED TRANSECT); Rippled alternating with flat sediment w/ polychaete tubes; ~5 very widely scattered small flat outcrops or small rocks <30 cm across [initially visible in side camera], anemone, nephthyid, cidaroid	
53	26 14.465	79 54.214	26.24108333	-79.90356667	Tie EW5	11	Pennatulid	1734-1736		POINT	N	3 Pennatulids on sediment (mass of sargassum)	
55	26 14.386	79 54.165	26.23976667	-79.90275000	Tie EW5	11	Depression	1741	927	POINT	N	large depression, sonar est. ~30 ft diameter; sediment slope	

58	26 14.276	79 54.189	26.23793333	-79.90315000	Tie EW5	11	Higher Cover Hard	1751	928		2 photos	Cluster of rocks, flat slabs & low outcrops to 1.3 m across; many small fish, nephthyids, anemones, cidaroid
59	26 14.273	79 54.192	26.23788333	-79.90320000	Tie EW5	11	Sediment	1755-1800	930-927		N	Flat and rippled sediment; anemones, cidaroids
60	26 14.113	79 54.285	26.23521667	-79.90475000	Tie EW5	12	Malacanthid	1805	934	POINT	N	Rippled sediment; possibly *Caulolatilus* [blueline?] tilefish [SIDE CAMERA]; cluster of anemones
61	26 14.069	79 54.3	26.23448333	-79.90500000	Tie EW5	12	Depression	1809-1835	927-948		N	5-6 depressions ~30-100 ft across, 20-30º slopes; sharp rims; chiefly rippled sediment, also areas of flat sediment with polychaete tubes; almost no exposed hard substrates
62	26 13.879	79 54.308	26.23131667	-79.90513333	Tie EW5	12	Low Cover Hard	1826	943	POINT	N	Flat white outcrop or consolidated sediment in bottom of one depression, with small fishes
63	26 13.879	79 54.308	26.23131667	-79.90513333	Tie EW5	12	Depression				N	Depression habitat continued
64	26 13.708	79 54.297	26.22846667	-79.90495000	Tie EW5	12	Malacanthid	1840	928	POINT	N	Alternating rippled & flat sediment with tubes; possible tilefish burrow [SIDE CAMERA]
65	26 13.75	79 54.299	26.22916667	-79.90498333	Tie EW5	13	Sediment	1840-1851	932		N	Flat sediment with low-relief ripples; ophiuroid, asteroids
66	26 13.557	079 54.294	26.22916667	-79.90498333	EW 5	14	Sediment	1854	927		N	END TIE EW5 - BEGIN EW 5; Rippled sediment
67	26 13.513	79 54.42	26.22521667	-79.90700000	EW 5	14	Depression	1857-1926	914-941		N	Depressions with exposed consolidated clay, obsolete ripples or smooth areas with tubes, some burrows, no attached fauna; 20-40 ft diam; max depth range 914-941 ft; cidaroid, asteroids
69	26 13.359	79 54.846	26.22265000	-79.91410000	EW 5	14	Malacanthid	1920-1923	914-941	POINT	N	*Caulolatilus* tilefish burrow in depression slopes
70	26 13.336	79 54.95	26.22226667	-79.91583333	EW 5	14	Malacanthid			POINT	N	*Caulolatilus* tilefish burrow in depression slopes
71	26 13.325	79 54.998	26.22226667	-79.91583333	EW 5	14	Sediment	1931	908		N	Alternating obsolete rippled sediment with flat textured sediment with small tubes; galatheids, anemones, Coronaster
	26 13.100	79 54.950			EW 5	15	Sediment	2016	881	POINT	N	**Last Cidaroid, 881 ft [CHECK LAT/LONG OF THIS DEPTH]**
76	26 12.459	79 58.933	26.20765000	-79.98221667	EW 5	17	Low Cover Hard	0110-0111	770		N	Sediment with depressions & few small bits of rubble 5- 15 cm; no attached fauna; galatheids
77	26 12.46	79 58.946	26.20766667	-79.98243333	EW 5	17	Sediment	0112-0124	770-759		N	Alternating obsolete rippled sediment with smooth sediment with small tubes & small mounds; some depressions & craters; galatheids, Coronaster, anemones, some cerianthids.
83	26 12.112	80 00.69	26.20186667	-80.01150000	EW 5	19	Low Cover Hard	0225	696	POINT	N	Same bottom; bit of rubble
84	26 12.112	80 00.69	26.20186667	-80.01150000	EW 5	19	Sediment	0225-0228	694-692		N	Rippled sediment disappearing; chiefly smoother sediment with small cones & depressions; Coronaster, anemones
	26 11.974	80 00.984			Tie EW4	20	Sediment	0250	663			END EW5, BEGIN Tie EW4; Sediment; no ripples; Coronaster, anemones
87	26 11.96	80 01.03	26.19933333	-80.01716667	Tie EW 4	20	Low Cover Hard	0251-0255	660-658		N	Sediment with few isolated clusters of small bits of rubble chiefly < 8cm, & 1 15-cm rock with anemones; Coronaster
88	26 11.96	80 01.03	26.19933333	-80.01716667	Tie EW 4	20	Sediment	0335-0345	654-660		N	Weakly bioturbated bottom - cones, depressions; anemones, Coronaster, cerianthids, 1 galatheid
89	26 11.702	80 01.105	26.19503333	-80.01841667	Tie EW 4	20	Low Cover Hard	0346	660		N	Small rubble piece with hydroid, another with anemone; Coronaster
90	26 11.696	80 01.105	26.19493333	-80.01841667	Tie EW 4	20	Sediment	0347-0404	660-665		N	Weakly bioturbated bottom - cones, crater; anemones, Coronaster,

												cerianthids	
	26 10.885	80 01.124			EW4		Sediment	0428-0430	665-670			END Tie EW4 - BEGIN EW4, sparsely bioturbated sediment	
93	26 10.823	80 01.065	26.18038333	-80.01775000	EW 4	22	Low Cover Hard	0431-0441	670-681		N	Isolated clusters or individual pieces of small low-relief rubble chiefly <10 cm, 2 to 20 cm; with hydroids, anemones, Coronaster. [0441] Cluster of low-relief rocks & slabs ~ 3 m across; individual slab ~ 1.3 m across; hydroids, anemones	
94	26 10.92	80 01.809	26.18200000	-80.03015000	EW 4	22	Sediment	0442-0450	681-699		N	Sparsely bioturbated sediment; anemones, Coronaster	
95	26 10.979	80 00.588	26.18298333	-80.00980000	EW 4	22	Low Cover Hard	0451	699	POINT	N	Possible small rock [or trash] with galatheid	
96	26 10.979	80 00.588	26.18298333	-80.00980000	EW 4	22	Sediment	0452-0503	699-710		N	Flat, sparsely bioturbated sediment with patches of rippled sediment; Coronaster, galatheids, anemones	
	26 11.801	79 57.36			EW4	26	Higher Cover Hard	0716-0756	842-867	POINT		FIRST HEXACTINELLIDS	
100	26 11.801	79 57.36	26.19668333	-79.95600000	EW 4	25	Higher Cover Hard	0702-0713	826-838		N	Phosphoritic rubble, rock outcrops, pavements and boulders in sediment; nephthyids, hydroids, anemones, Coronaster; passing to Aphrocallistes, hexactinellids, Phakellia, pachastrellids, Geodia, lithistids, Isididae, primnoid, nephthyids, anemones, echiurans	**Quant Photo Site 2**
	26 11.918	79 56.474			EW 4	27	Higher Cover Hard	0811	880	POINT		**First cidaroid urchin**	▼
103	26 11.916	79 56.463	26.19860000	-79.94105000	EW 4	27	Low Cover Hard	0811-0832	883-901		N	Flat or rippled sediment with isolated clusters or individual small rocks and rubble chiefly <20 cm, occas rock to 50 cm, rare flat slab to 1 m; chiefly anemones & nephthyids; echiurans, sponge, few small octocorals, cidaroids	▼
104	26 11.878	79 56. 072	26.19796667	-79.93333333	EW 4	27	Sediment	0832-0836	901-910		N	Flat or rippled sediment; 2 isolated rocks	
105	26 11.863	79 55.987	26.19771667	-79.93311667	EW 4	28	Low Cover Hard	0837-0839	910-912		N	Flat sediment with isolated individual rubble & small rocks or scattered clusters,anemones, nephthyids, echiurans, cidaroid	
106	26 11.853	79 55.948	26.19755000	-79.93246667	EW 4	28	Sediment	0839-0843	912-916		N	Sediment with little bioturbation	
107	26 11.846	79 55.885	26.19743333	-79.93141667	EW 4	28	Low Cover Hard	0843-0900	916- 934		N	Chiefly rippled sediment, some flat areas with tubes, with widely scattered, isolated rocks, a small veneered slab; 1 big rock a few ft across; anemones, nephthyids, echiurans, cidaroid	
108	26 11.819	79 55.619	26.19698333	-79.92698333	EW 4	28	Sediment	0903-0917	936-941		N	Sediment with little bioturbation; anemones, numerous ophiuroids	
110	26 11.738	79 55.099	26.19563333	-79.91831667	EW 4	29	Depression	0940-0942	954-943	POINT	N	Depression with tiny rocks scattered across surface as well as a few rocks up to 1 m across; ~15 ft max depth; cidaroids, anemones	
111	26 11.736	79 55.064	26.19560000	-79.91773333	EW 4	29	Sediment	0944-0958	943		N	Flat sediment with some bioturbation, few ripples; ophiuroids, anemones, cidaroids	
	26 11.717	79 54.952	**ADD TO MAP**		EW4	29	Pennatulid	0952	943	POINT		Pennatulid on sediment [TWO MENTIONED IN NOTES; ONE VISIBLE ON TAPE; NO AUDIO]	
113	26 11.652	79 54.461	26.19420000	-79.90768333	EW 4	30	Low Cover Hard	1036-1039	952-950		N	Few isolated small rocks (5-30 cm) & few clusters of small rocks & low veneered slabs (to 0.75 m) with numerous anemones, Flytrap anemone; anemones also on sediment	
114	26 11.65	79 54.432	26.19416667	-79.90720000	EW 4	30	Sediment				N	Sediment	

115	26 11.651	79 54.412	26.19418333	-79.90686667	EW 4	31	Pennatulid	1040-1056	950-952		N	Alternating raised rippled sand waves & flat sediment with tubes; galatheid, **several sea pens [**at most 2 in one field; otherwise widely isolated; some in side camera], abundant anemones on sediment, 2-3 up to 12 m^{-2}; 1 rock with anemone.	
	26 11.555	79 54.166			Tie EW 3	31	Pennatulid	1055	952			END EW 4 - BEGIN TIE EW 3; Flat sediment with little bioturbation, some ripples; numerous anemones, up to 6-7 m-2; cidaroids, sea pens	
119	26 11.052	79 54.194	26.18365000	-79.90360000	Tie EW 3	32	Sediment	1134			N	End sea pens; sediment to end of transect	
120	26 11.019	79 54.216	26.18365000	-79.90360000	EW 3	32	Sediment	1135-1150	964-963		N	BEGIN EW3; Alternating flat and rippled sediment; occasional bioturbation; anemones, cidaroids, ophiuroids, galatheids	
121	26 10.957	79 54.521	26.18261667	-79.90868333	EW 3	32	Pennatulid	1150	963	POINT	N	Flat or rippled sediment; possible veneer over hard substrate; sea pens, ophiuroid, cidaroid, anemone, galatheid	
124	26 10.884	79 54.876	26.18140000	-79.91460000	EW 3	33	Low Cover Hard	1207	966-968		N	Scattered clusters of low-relief rocks and slabs a few meters across separated by expanses of sediment; rocks up to 0.8 m across & pavement 1.5 m across; mostly barren with little fauna, few anemones, flytrap anemone, echiurans, cidaroids	
125	26 10.871	79 54.932	26.18118333	-79.91553333	EW 3	33	Sediment	1211	963		N	Rippled sediment; passing to flat textured bottom with tiny tufts and worm tubes, cones and depressions; either consolidated with a veneer of sediment with numerous depressions and cones or not completely consolidated; some areas of obsolete ripples; numerous ophiuroids, anemone	
126	26 10.867	79 54.948	26.18111667	-79.91580000	EW 3	33	Pennatulid	1212	964	POINT	N	Obsolete rippled sediment; sea pen in side camera	
130	26 10.544	79 54.508	26.17573333	-79.90846667	EW 3	34	Low Cover Hard	1324	896	POINT	N	Rock with anemone; possible outcrops to sides	**Quant. Photo Site 3**
131	26 10.544	79 54.508	26.17573333	-79.90846667	EW 3	34	Sediment	1324	894-889		N	Obsolete rippled sediment	▼
132	26 10.521	79 56.617	26.17535000	-79.94361667	EW 3	34	Low Cover Hard	1326-1328	889		N	Rock, few scattered slabs & low hardground with anemones	▼
133	26 10.521	79 56.617	26.17535000	-79.94361667	EW 3	35	Higher Cover Hard	1328	871-865		N	Low-relief rocky outcrops, scattered rocks & rubble; various sponges, pachastrellids, cup sponges, geodiid, Phakellia, Isididae, primnoids, other gorgonians, nephthyids, numerous anemones, antipatharian, echiurans, cidaroids, asteroids; separated by expanses of sediment	▼
134	26 10.414	79 57.148	26.17356667	-79.95246667	EW 3	35	Sediment	1358	865	POINT	N	Sediment; passing to flat sparsely bioturbated sediment with tufts; ophiuroids, asteroids, galatheids	**Quant. Photo Site 4**
	26 10.41	79 57.163			EW 3	35-36	Higher Cover Hard	1359-1730	871-856		Photos	More hard bottom; large octocoral, Phakellia, anemones, echiurans, flytrap anemone; scattered low-relief hardbottom - rubble & rubble fields, rocks, veneered pavement - separated by wide sediment expanses; sponges, lithistids, hexactinellids, pachastrellids, Isididae, primnoids, anemones; stylasterid; turfy sediment; some hard bottoms relatively barren	▼

	26 10.377	79 57.306			EW 3	36	Higher Cover Hard	1718-1730	856-867	POINT		LAST HEXACTINELLIDS	
	26 10.337	79 57.500			EW 3	36	Sediment	1730	867			Sparsely bioturbated sediment; ophiuroids, asteroids, galatheids	
	26 09.821	80 00.218			EW 3	40	Sediment	2015	734			Off transect; Avenger airplane with epifauna; hydroids, gorgonians, small corals	
146	26 09.583	80 01.061	26.16275000	-80.00458333	Tie EW 2	42	Sediment	2054-2055	701		N	END EW3; BEGIN TIE EW 2; Sparsely bioturbated sediment	
147	26 09.547	80 01.104	26.15911667	-80.01840000	Tie EW 2	42	Sediment	2057	698-692	POINT	N	Sparsely bioturbated sediment; debris with hydroids, small rubble cluster, <10-cm; anemones	
155	26 08.8	80 01.105	26.14666667	-80.01841667	Tie EW 2	43	**RE-MAP AS ARTIFICIAL**	2207	681	POINT	N	tilefish around sailboat wreck; no obvious burrows **NOT TILEFISH - OMIT AS TILEFISH POINT; RE-IDENTIFY AS ARTIFICIAL POINT**	
160	26 08.606	80 00.309	26.14666667	-80.01841667	EW 2	46	Sediment	2309-2340	732-752		N	END TIE EW2 - BEGIN EW2; Bioturbated sediment (mounds, depressions); cluster of polychaete tubes; Coronaster	
162	26 08.8	80 01.105	26.14666667	-80.01841667	EW 2	47	Sediment	2350-0029	761-777	POINT	N	Flat bioturbated sediment (mounds, burrows) with small tubes (textured) and fine growth alternating with raised areas of obsolete rippled sediment; Coronaster, galatheids, **first cidaroid at 768 ft**	
167	26 09.243	79 58.035	26.15405000	-79.96725000	EW 2	50	Higher Cover Hard	155	840-845		Photos	Scattered small & large rocks & slabs, small outcrop separated by expanses of sediment; hydroids, anemones, Aphrocallistes, sponge, primnoid, Isididae, asteroids	**Quant . Photo site 5**
	26 9.251	79 58.013			EW 2	50	Sediment	156	842			Flat sediment with fine tufts or tubes	
	26 9.261	79 57.966			EW 2	50	Higher Cover Hard	159	845			Scattered low relief flat slabs, outcrops & rocks on sediment, 1-m boulder; hydroids, anemones, hexactinellid	
	26 9.273	79 57.904			EW 2	50	Higher Cover Hard	202	845	POINT		FIRST HEXACTINELLID	
168	26 09.281	79 57.88	26.15468333	-79.96466667	EW 2	50	Sediment	203	847		N	Bioturbated sediment; Coronaster;asteroids	
	26 9.31	79 57.775			EW 2	50	Higher Cover Hard	208	847		Photos	Hardbottom - slabs, boulders, rubble -separated by areas of sediment; Coronaster, Phakellia, anemones, primnoids, nephthyids, Isididae, echiurans	
	26 9.462	79 57.414			EW 2	50	Higher Cover Hard	222	862			**MOVING TO EAST END OF EW 2 TO RUN BACK TO WEST - DO NOT INCLUDE GAP FROM THIS POINT TO NEXT IN SHIP'S TRACK**	
170	26 09.978	79 54.193	26.16630000	-79.90321667	EW 2	51	Higher Cover Hard	351	925		Photos	**RESUME TRANSECT**; 8-30-cm rocks, rubble, boulders, chiefly 1-2 ft relief (1 up to 3 ft); some slabs, pavement, veneered hardbottom, some expanses of sediment; hexactinellids,	**Quant. Photo site 6**
171	26 09.899	26 09.899	26.16498333	-79.91343333	EW 2	51	Pennatulid	0423-0432	968		N	Rippled sediment with few sea pens, anemones, 1-2 isolated 5-10 cm rubble	▼
172	26 09.899	79 54.806	26.16498333	-79.91343333	EW 2	51	Sediment	423	968		N	Rippled sediment w few anemones	
	26 09.874	79 55.083			EW 2	52	Pennatulid	436	964	POINT		Sea pen on rippled sediment	

175	26 09.766	79 55.985	26.16276667	-79.93308333	EW 2	53	Low Cover Hard	516	939-912		N	Hardbottom rocks, rubble & slabs with 10-30 cm rocks separated by sediment expanses; hexactinellids, anemones, flytrap anemone, nephthyids, hydroids, Isididae, cidaroids	**Quant. Photo site 7**
176	26 09.677	79 56.289	26.16128333	-79.93815000	EW 2	53	Higher Cover Hard	0531	912-914		N	Low-relief pavement, fly trap, sponge, Isididae, cidaroid	▼
177	26 09.65	79 56.407	26.16083333	-79.94011667	EW 2	53	Low Cover Hard	0536	916		N	Sediment with a few rocks	▼
178	26 09.648	79 56.419	26.16080000	-79.94031667	EW 2	53	Sediment	537	916-908		N	Sparsely bioturbated sediment; cidaroid, asteroid	▼
179	26 09.572	79 56.717	26.15953333	-79.94528333	EW 2	53	Low Cover Hard	548	907-905		N	Two isolated areas of hardbottom - 1 ft-rocks, larger slabs; few widely isolated small rocks & rubble; anemones; hydroid, nephthyid; **boat?**	▼
180	26 09.557	79 56.771	26.15928333	-79.94618333	EW 2	53	Sediment	0550	904		N	Sediment with tubes	▼
181	26 09.547	79 56.846	26.15911667	-79.94743333	EW 2	54	Higher Cover Hard	0554-0634	896-860		Photos	Low-relief hardbottom with sediment veneer, 10-20-cm rubble; cobbles, boulders, slabs, low rugged outcrops, separated by sediment expanses with tubes;	▼
182	26 09.547	79 56.846	26.15911667	-79.94743333	EW 2	54	Sediment	0633			N	Just past site where transect was stopped when heading East earlier; overlapping until hardbottom is cleared	▼
183	26 09.547	79 56.846	26.15911667	-79.94743333	EW 2	55	Higher Cover Hard	636	845-838		Photos	Large boulders with higher relief, slabs, outcropping pavement, 7-8 ft ledge; pachastrellid, anemones, hydroid, Isididae, primnoids.	▼
184	26 09.273	79 57.872	26.15455000	-79.96453333	EW 2	55	Sediment	0641			N	Sediment	▼
	26 09.260	79 57.918			EW 2	55	Sediment	0643	838			END EW 2	
185	26 14.475	79 55.13	26.24125000	-79.91883333	EW6 Rep	56	Low Cover Hard	0813-0817	854		Photos	BEGIN REPEAT OF EW6; rubble in rippled sediment, rocks to 20 cm, few 0.5-m slabs; anemones, nephthyids, cidaroids	
186	26 14.443	79 55.216	26.24071667	-79.92026667	EW6 Rep	56	Higher Cover Hard	0819-0846	851-865		N	Rubble with rocks more crowded & larger, 20-50 cm, with some low pavement to 1.8 m across, alternating with areas of rippled sediment with sparse rubble & isolated rocks; hard substrate epifauna varies from numerous to sparse	
187	26 14.303	79 55.894	26.23838333	-79.93156667	EW6 Rep	56	Sediment	0846-0853	865		N	Rippled & bioturbated sediment; cidaroids	
193	26 14.046	79 57.253	26.23410000	-79.95421667	EW6 Rep	58	Low Cover Hard	0941	851	POINT	N	30-cm rock with anemone	
194	26 14.046	79 57.253	26.23410000	-79.95421667	EW6 Rep	58	Sediment	0943	851	POINT	N	Bamboo coral??[NOT VISIBLE ON REVIEW OF TAPE; NO AUDIO]	
195	26 14.029	79 57.340	26.23410000	-79.95421667	EW6 Rep	58	Sediment	944	?	POINT	N	Isolated flat white outcrop ~75-cm across; barren	
	26 13.712	79 58.991			EW6 Rep	59	Sediment	1044	?		N	END EW6 Repeat; Bioturbated sediment alternating with patches of rippled sediment	
199	26 13.481	79 57.775	26.23410000	-79.95421667	New NE B (S)	60	Sediment	1455-1549	813-860		N	BEGIN NEW NE B (SOUTH) Flat textured sediment (worm tubes) with some bioturbation (mounds, depressions) alternating with raised rippled sand waves; Coronaster, galatheids	
200	26 13.489	79 57.061	26.22481667	-79.95101667	New NE B (S)	60	Low Cover Hard	1546-1547	860	POINT	N	Small rubble bit (~15-cm) in depression with anemone; galatheids	

201	26 13.489	79 57.061	26.22481667	-79.95101667	New NE B (S)	61	Sediment	1550-1553	862		N	Flat textured sediment (worm tubes) with some bioturbation (mounds, depressions) alternating with raised rippled sand waves; Coronaster, galatheids
202	26 13.527	79 56.878	26.22545000	-79.94796667	New NE B (S)	61	Low Cover Hard	1554-1557	862-863	POINT	N	Same bottom, one small rock 30-cm (2 other 5-cm bits); anemone, hydroids, galatheids, Coronaster
203	26 13.527	79 56.878	26.22545000	-79.94796667	New NE B (S)	61	Sediment	1558-1643	863-876	POINT	N	Flat textured sediment (worm tubes) with some bioturbation (mounds, depressions) alternating with raised rippled sand waves; Coronaster, galatheids; anemones, ophiuroids, 1 dark cerianthid, **1st cidaroid in 867 ft**; ripples declining at 871 ft
205	26 13.842	79 55.338	26.23070000	-79.92230000	New NE B (S)	62	Low Cover Hard	1710	882-887		Photos	Scattered rubble & rocks 5-30 cm; hydroids, anemones, cidaroids, cerianthid
206	26 13.973	79 54.709	26.23110000	-79.92081667	New NE B (S)	62	Sediment	1715-1723	889-896		N	Rippled sediment with sparse bioturbation; cidaroids, asteroid, ophiuroid; Flat sediment with worm tube turf alternating with elevated areas of rippled sand w sparse bioturbation; anemone, ophiuroid, cidaroid
209	26 14.027	79 54.47	26.23378333	-79.90783333	New NE B (S)	63	Pennatulid	1748		POINT	N	One small sea pen on rippled sediment
210	26 14.032	79 54.442	26.23386667	-79.90736667	New NE B (S)	63	Depression	1750	930-932		Photos	Depression with rubble on bottom; 13 ft deep (to 943 ft), 30-40 ft across, 20-30º slope; anemone; sea pen
211	26 14.033	79 54.438	26.23388333	-79.90730000	New NE B (S)	63	Pennatulid	1750		POINT	N	Sea pen on depression floor
212	26 14.055	79 54.329	26.23425000	-79.90548333	New NE B (S)	63	Sediment	1755	932-937		N	Out of depression; Rippled sediment with sparse bioturbation; passing to flat sediment with turf alternating with elevated areas of rippled sand; cidaroids, anemones, asteroid
213	26 14.078	79 54.223	26.23463333	-79.90371667	New NE B (S)	63	Pennatulid	1802	945	POINT	N	Sea pen; no ripples
	26 14.08	79 54.142			New NE B (S)	63	Sediment	1806	?		N	END NEW NE B (SOUTH); Flat sediment with worm tube turf alternating with elevated areas of rippled sand w sparse bioturbation
214	26 14.161	79 54.152	26.23463333	-79.90371667	New NE Tie A-B	64	Sediment	1816-1836	928		N	BEGIN NEW NE TIE A-B: Flat sediment with worm tube turf alternating with elevated areas of rippled sand w sparse bioturbation; anemone, ophiuroid, cidaroid; galatheid, cerianthid
216	26 14.543	79 54.126	26.24238333	-79.90210000	New NE Tie A-B	64	Depression	1856	932-925		N	Begin depressions, max. relief 11 ft (932-934 ft); consolidated clay or rock bottom; anemones, cidaroid, asteroid
217	26 14.611	79 54.133	26.24351667	-79.90221667	New NE Tie A-B	64	Pennatulid	1902-1911	934-925		N	Isolated sea pens
219	26 14.718	79 54.136	26.24530000	-79.90226667	New NE Tie A-B	65	Depression	1913	927		N	Rippled sediment w sparse bioturbation; area rife with karst topographic features and low/mid relief sediment dunes
220	26 14.747	79 54.137	26.24578333	-79.90228333	New NE Tie A-B	65	Sediment	1914-1930	927-917		N	End karst/depressions; Rippled sand waves alternating with flat sediment; cidaroids, anemones
221	26 14.966	79 54.143	26.24943333	-79.90238333	New NE Tie A-B	65	Low Cover Hard	1936	917-905		N	Isolated clusters of small rocks to 30 cm or single small rocks in sediment; anemones, cidaroids, Isididae, paramuriceid

	26 14.979	79 54.140			New NE Tie A-B	65	Sediment	1936	?		N	Rippled & flat turfy sediment	
222	26 14.992	79 54.14	26.24988333	-79.90233333	New NE Tie A-B	65	Higher Cover Hard	1937	900-890		Photo series	Rocks, rubble, low-relief irregular outcrops and veneered pavement to 50% rock cover, separated by wide expanses of sediment; cidaroids, anemone, nephthyid, antipatharians; few sea pens on sediment	**Quant. Photo site 8**
223	26 14.275	79 54.137	26.24988333	-79.90233333	New NE Tie A-B	65	Low Cover Hard	1953	890		N	Small isolated boulders[?]; anemone, pachastrellid, hexactinellids?	▼
224	26 15.297	79 54.139	26.24988333	-79.90233333	New NE Tie A-B	65	Higher Cover Hard	1954	885		Photo series	Solid pavement; antipatharian, anemone, Isididae, vase sponge off side	▼
225	26 15.378	79 54.136	26.24988333	-79.90233333	New NE Tie A-B	65	Low Cover Hard	1958-2000	885-892		N	Scattered rocks, 5-10-cm rubble field; cidaroids, Isididae, sponges, anemone, hydroids	▼
226	26 15.428	79 54.137	26.24988333	-79.90233333	New NE Tie A-B	65	Higher Cover Hard	2001-2006	890		Photo series	Rubble, outcrops, 10-30-cm boulders; 1-2-ft slabs; Aphrocallistes, hexactinellids, other sponges, hydroids, antipatharians, nephthyids, gorgonian, echiurans, cidaroids	▼
227	26 15.534	79 54.14	26.25890000	-79.90233333	New NE Tie A-B	66	Higher Cover Hard	2007-2014	885		Photo series	Rubble fileds, rocks, boulders up to 30 cm, veneered outcrops; Aphrocallistes, geodiid, pachastrellids, Phakellia, hexactinellids, nephthyids, numerous Isididae, gorgonians, antipatharians, numerous echiurans,	▼
	26 15.681	79 54.130			New NE Tie A-B	66	Higher Cover Hard	2014			Photo series	Rubble field, chiefly <15 cm, anemones, nephthyids	▼
	26 15.715	79 54.126			New NE Tie A-B	66	Higher Cover Hard	2016	889		Photo series	Veneered low-relief outcrops, pavements, rocks, alternating with expanses of sediment and fields of rubble; antipatharian, anemones, echiurans, pachastrellid etc.	▼
	26 15.765	79 54.13			New NE Tie A-B	66	Higher Cover Hard	2021				END NEW NE TIE A-B	▼
228	26 15.765	79 54.13	26.26275000	-79.90216667	New NE A (N)	66	Higher Cover Hard	2022-2027	885-883		N	BEGIN NEW NE A (NORTH)15-20-cm boulders to larger rocks; Aphrocallistes, hexactinellids, Phakellia, nephthyids, anemones, Isididae, antipatharians, echiurans, cidaroids	▼
229	26 15.741	79 54.227	26.26275000	-79.90216667	New NE A (N)	66	Sediment	2027	880-881		N	Flat or rippled sand; no hard substrate, antipatharian	
230	26 15.723	79 54.282	26.26275000	-79.90216667	New NE A (N)	66	Low Cover Hard	2031-2037	878-876		N	Fields of sparse to abundant rubble chiefly <10 cm with occasional areas of larger rocks, slabs & outcrops to 0.75 m, still very low relief; chiefly anemones, nephthyids, with sparse Aphrocallistes, geodiid, hexactinellids, Isididae, antipatharians, echiurans, cidaroids	
	26 15.706	79 54.397			New NE A (N)	66		2038				**STANDING BY; DO NOT INCLUDE GAP FROM THIS POINT TO NEXT IN SHIP'S TRACK**	
231	26 15.722	79 54.399	26.26275000	-79.90216667	New NE A (N)	66-68	Higher Cover Hard	2048-2242	867-858		N	Large boulders, slabs, pavement, boulder field with smaller rocks, mixed with fields of sparse to abundant rubble; Aphrocallistes, Phakellia, pachastrellids, geodiid, anemones, nephthyids, Isididae, gorgonians, numerous antipatharians, echiurans, cidaroids	
	26 15.428	79 55.829			New NE A (N)	68	Higher Cover Hard	2207	818	POINT		LAST HEXACTINELLID	

235	26 15.269	79 56.615	26.25448333	-79.94358333	New NE A (N)	68	Low Cover Hard	2243-2244	836-847		N	Isolated small rocks and scattered clusters of small rocks, a few up to 0.4 m, occas veneered slab to 1 m across, on rippled sediment; hexactinellid, anemone, Isididae, antipatharians, cidaroids, Coronaster
	26 15.267	79 54.622			New NE A (N)	68	Low Cover Hard	2243	836			
236	26 15.259	79 54.653	26.25431667	-79.91088333	New NE A (N)	68	Sediment	2245			N	Rippled or flat bioturbated sediment **OMIT - JUST A VERY LOCAL SEDIMENT AREA**
237	26 15.241	79 56.736	26.25401667	-79.94560000	New NE A (N)	68	Low Cover Hard	2250			N	Rubble field with isididae, anemones,
238	26 15.240	79 56.742	26.25400000	-79.94570000	New NE A (N)	68	Sediment	2250	847		N	Rippled sand waves (up to 8-ft vertical relief); interspersed with smooth areas with worm tubes
239	26 15.224	79 56.855	26.25373333	-79.94758333	New NE A (N)	68	Malacanthid	2255	845	POINT	N	Tilefish burrow; more little rubble
	26 15.224	79 56.855			New NE A (N)	68	Sediment	2256-2300	847	POINT		**Last cidaroids**
241	26 15.197	79 56.961	26.25328333	-79.94935000	New NE A (N)	68	Low Cover Hard	2301		POINT	N	Patch of 10-30-cm rubble at base of slope
242	26 15.196	79 56.965	26.25328333	-79.94935000	New NE A (N)	68	Sediment				N	Flat or rippled sediment
243	26 15.190	79 56.989	26.26566667	-79.94958333	New NE A (N)	69	Sediment	2302-2307	845-842		N	Rippled sediment; anemone, Coronaster
	26 15.173	79 57.113			New NE A (N)	69	Low Cover Hard	2308-2314	840-836			Obsolete rippled sediment with very widely scattered variously sized rocks to 1-m across; anemones, gorgonians, antipatharians, Coronaster
245	26 15.156	79 56.226	26.26566667	-79.94958333	New NE A (N)	69	Sediment	2315-2337	838-820		N	Rippled & sparsely bioturbated sediment; Coronaster
246	26 15.071	79 56.630	26.26566667	-79.94958333	New NE A (N)	69	Depression	2331	829		N	7-ft deep depression
	26 15.047	79 57.778			New NE A (N)	69	Sediment	2337	~820-809			END NEW NE A (NORTH); BEGIN NEW N-S; Rippled & sparsely bioturbated sediment; passing to rippled sand waves alternating with narrow strips of flat bioturbated sediment; one flat rock Coronaster, galatheids, anemone, asteroids
249	26 14.616	79 57.855	26.24360000	-79.96425000	New N-S	70	Low Cover Hard	7	808	POINT	N	Rock with anemone & hydroids, adjacent flat white rocks 1-m across w very few anemones
250	26 14.539	79 57.852	26.24231667	-79.96420000	New N-S	70	Low Cover Hard	12		POINT	N	Small 8-cm rock with anemones
251	26 13.912	79 57.85	26.23186667	-79.96416667	New N-S	70	Low Cover Hard	44	817	POINT	N	Flat rock, no fauna on it
253	26 13.74	79 57.851	26.22900000	-79.96418333	New N-S	71	Artificial	0115	822	POINT	photo 166	Fishing boat
255	26 11.62	79 57.850	26.19620000	-79.96413333	New N-S	73	Sediment	0244-0251	829-831		N	END OF NEW N-S; as previous - obsolete rippled sediment sand waves, advancing face is steep to north, run E-W, separated by areas of smooth bioturbated sediment with small mounds; Coronaster

Abundance Estimate of the Gulf of Maine Harbor Porpoise

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ABSTRACT

Shipboard surveys were conducted in the summer of 1991 to estimate the abundance of harbor porpoises, *Phocoena phocoena*, in the northern Gulf of Maine and lower Bay of Fundy. The best estimate is 37,500 (95% CI: 26,600 to 86,400). The estimate is based on the independent team sighting procedure from one ship, which allowed the estimation of g(0): 0.72 (SE=0.06). The abundance estimate presented is substantially higher than previous estimates for the area. This is due to the more extensive areal coverage and the inclusion of g(0) into the estimate. While the statistical precision that was reported here included some sources of uncertainty, others remain to be addressed. The most important of these are the potential downward bias due to animals avoiding the vessel, the highly aggregated spatial distribution of porpoises and the largely unknown effects of heterogeneity of observers, platforms and environmental conditions.

KEYWORDS: HARBOUR PORPOISE; NORTH ATLANTIC; SURVEY-SHIP; ASSESSMENT; g(0).

INTRODUCTION

There are five past surveys that estimated the abundance of harbor porpoise in the Gulf of Maine-Bay of Fundy region (Gaskin, 1977; Prescott *et al.*, 1981; Winn, 1982; Kraus *et al.*, 1983b; Gaskin *et al.*, 1985). Estimates ranged from roughly 3,000 to 15,000 animals. They provided minimum estimates of abundance because of their limited ranges and because of failures of assumptions made in the analyses. In 1991, two surveys were conducted over a much broader area using line transect survey techniques developed to overcome some of the previous methodological problems (Kraus *et al.*, 1983a; Barlow, 1988; Butterworth and Borchers, 1988; Polacheck, 1989; 1994a; b; Polacheck and Smith, 1989; 1990; Øien, 1990; Polacheck and Thorpe, 1990; Polacheck *et al.*, 1990; 1994).

In this paper, I present a new population abundance estimate using data collected during the two 1991 surveys. The reliability of the abundance estimate is assessed and potential sources of uncertainties that were not accounted for are discussed. This paper updates the abundance estimate reported in Smith *et al.* (1991), Anon. (1992) and Read *et al.* (1993).

METHODS

Field procedures

From 22 July – 31 August 1991, a shipboard sighting survey was performed in the offshore waters of the Gulf of Maine-lower Bay of Fundy-southern Scotian shelf area. From 3 – 17 August 1991 a second survey was performed in the shallow inshore bays off Maine (Fig. 1). 'Passing mode' line transect methods (Burnham *et al.*, 1980; Butterworth and Borchers, 1988) were used on both vessels. The independent team sighting procedure was used on

one of the ships to allow the estimation of $g(0)$, the probability of detecting a group of animals on the trackline.

The survey area was stratified first by depth, then within the deeper, offshore region by expected harbor porpoise density. This resulted in four strata, referred to as the 'high density', 'intermediate density', 'low density' and the shallower 'inshore' strata (Fig. 1). The abundance estimates for the high, intermediate and low density strata were obtained from data collected aboard the *R/V Abel-J* (106-ft, 15-ft draft). The abundance estimate for the inshore stratum was obtained from data collected aboard both vessels because the *R/V Abel-J* could not enter all of the shallow inshore bays and the smaller vessel, *M/V Sneak Attack* (48-ft, 4-ft draft), could not accommodate the independent team sighting procedure.

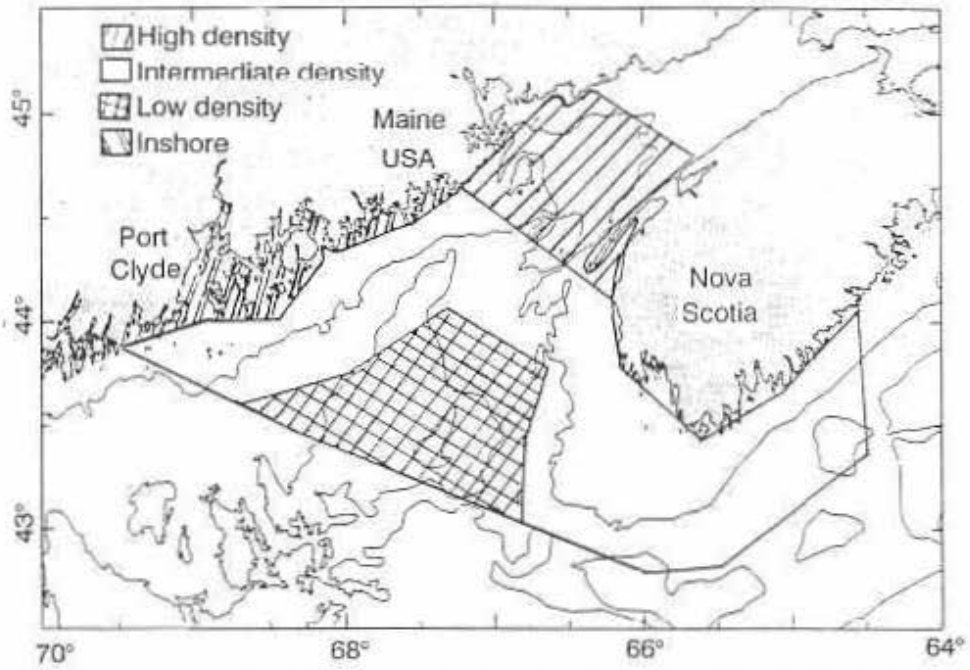

Fig. 1. Study area located in the Gulf of Maine, lower Bay of Fundy and part of the Nova Scotian shelf. Study area divided into four strata: high density; intermediate density; low density; and inshore. Dotted lines represent the 50 and 100 fathom depth contour lines.

Sneak Attack survey

Line transect survey methods were performed in Beaufort sea state two or less along 7 nautical mile (n.mile) transects within four geographical blocks: (A) Penobscot Bay; (B) Jericho and Blue Hill Bays; (C) Frenchman Bay; and (D) Pleasant, Englishman and Machias Bays (Fig. 2). The blocks were assigned on the basis of possible habitat divisions and to facilitate allocation of survey lines. Each block was divided into an inshore and offshore area. The inshore area corresponded to the inshore stratum, defined above, and was delimited as the waters inshore of lines connecting major headlands. The offshore area encompassed waters out to 5 n.miles offshore these lines.

Trackline mileage was allocated in proportion to the surface area of navigable waters. Survey tracklines were divided into 7 n.mile transects (Fig. 3). The sighting team consisted of three observers, a recorder and a helmsman. People rotated among positions every 30 minutes, which was approximately the length of one transect. The ship traveled at 14 knots.

For every detected marine mammal, the data recorded were the position (using LORAN C), species, group size (best, high and low estimate), sighting cue, number of calves, identity of the observer responsible for the sighting, radial distance (estimated visually) and bearing to the initial sighting position (facilitated by the placement of markers of measured radial degrees around the observation area). In addition, at the beginning of each transect and at all marine mammal sightings, vessel speed, water depth, surface water temperature, sea state, swell, weather and glare conditions were recorded (Read and Kraus, 1991).

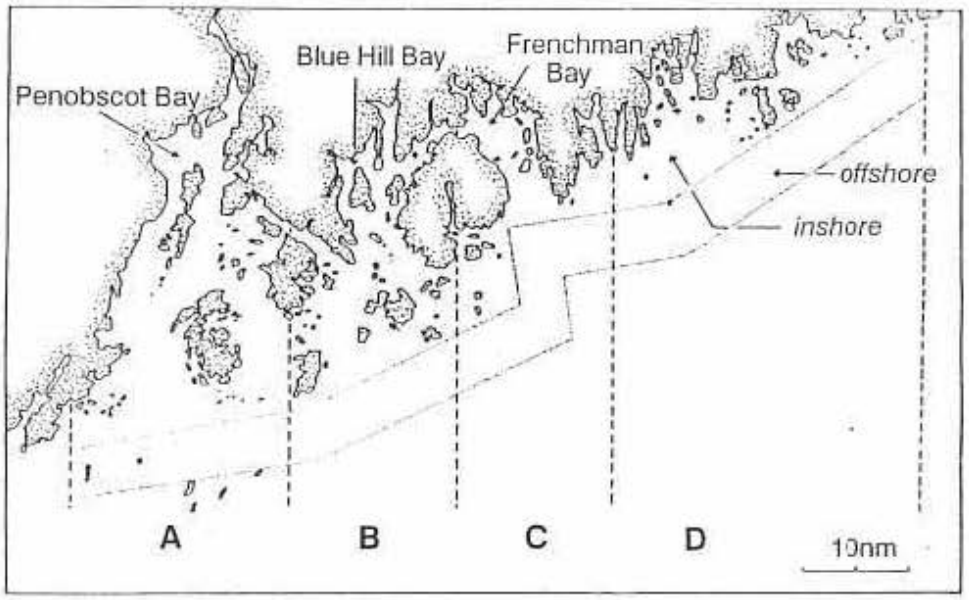

Fig. 2. Area surveyed by the *M/V Sneak Attack* which is divided into four geographical blocks (A, B, C, D). Each block is divided into an inshore area, corresponding to the inshore stratum shown in Fig. 1 and an offshore area 5 n.miles off the inshore area.

Abel-J survey

Trackline mileage in the high density and intermediate density strata was approximately proportional to the stratum area. The trackline length in the low density stratum was less than proportional to the area. The trackline mileage allocation was accomplished by dividing each stratum into 'boxes', each approximately 600 n.miles^2. Within each box, 90–100 n.miles were surveyed, roughly one day's effort. The order in which the boxes were surveyed was chosen randomly with the constraint that the box to be surveyed on the next day could be reached by traveling during the night. The tracklines within a box followed a zig-zag pattern running along hypothesized density gradients (i.e. perpendicular to density contour lines). Because both a northeastern-southwestern (Kraus *et al.*, 1983b) and an

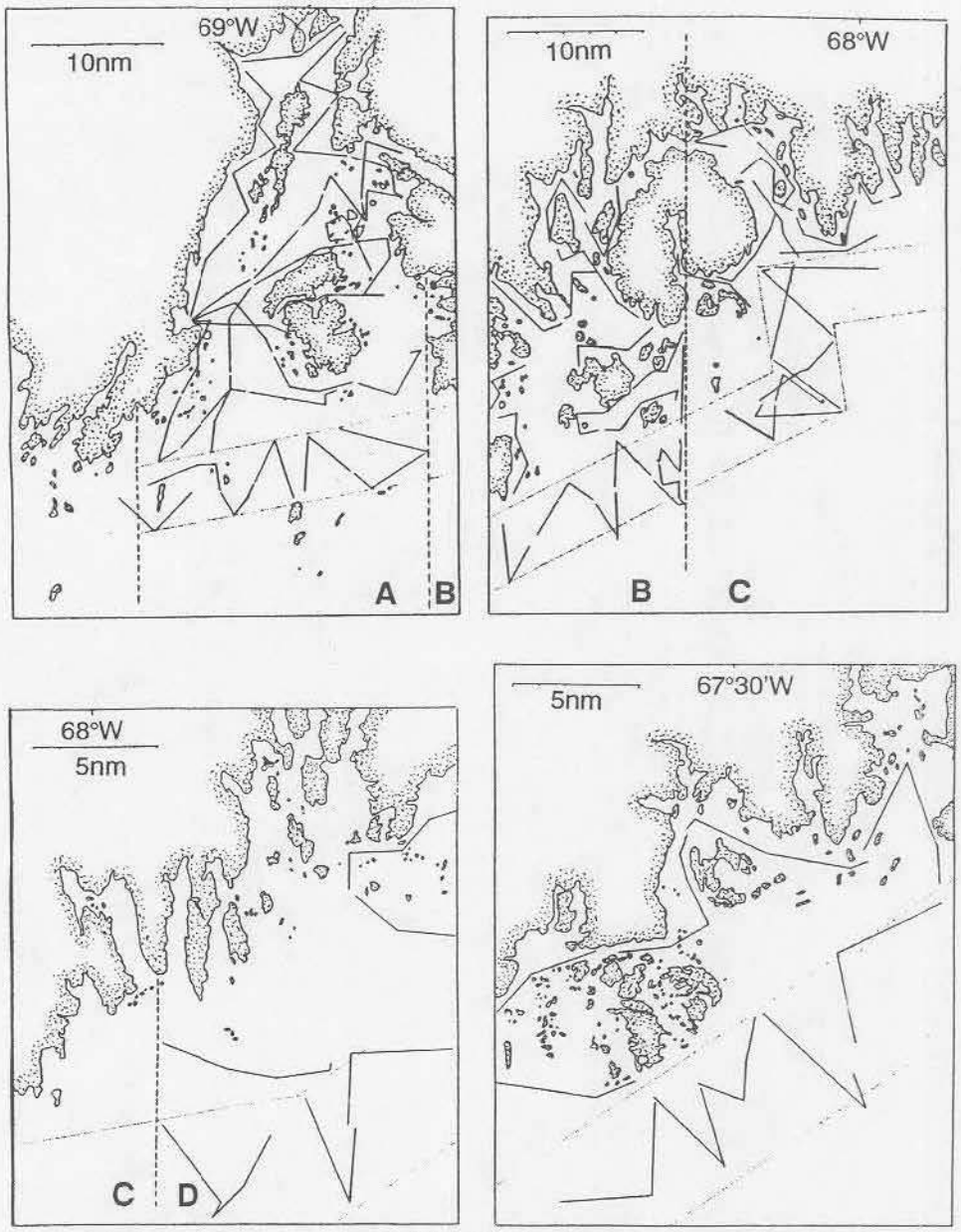

Fig. 3. Tracklines surveyed by the *M/V Sneak Attack* in the four geographical blocks.

inshore-offshore gradient (Gaskin, 1977) had been proposed, some day's tracklines ran north-south (parallel to the shoreline) while other day's ran inshore-offshore (perpendicular to the shoreline) (Fig. 4). The starting point within a box was chosen randomly, again with the constraint that the starting point could be reached by travel during the night.

The tracklines were divided into 'transects' and 'legs' to facilitate estimating a bootstrap confidence interval of the abundance estimate, as has been done in other marine mammal sighting surveys (Øien, 1990; Gerrodette and Wade, 1991). There were 4–8 'transects' per day, where a transect was defined as the time during which the ship's heading and speed was constant. A transect was made up of a consecutive series of 'legs', where a leg was defined as the time during which all conditions were constant. Conditions considered were environmental factors and position of observers, in addition to ship's speed and heading .

The independent observer sighting procedure (Butterworth and Borchers, 1988) was used throughout the survey to allow estimation of abundance corrected for $g(0)$. Two physically separated teams of observers searched simultaneously for marine mammals using the unaided eye. One team was located on the 'upper' crow's nest, 14m above the sea surface, while the other team was located vertically below the upper team on the 'lower' crow's nest, 9m above the sea surface. The two teams could not see or hear each other.

There were four observers per team. Observers did not rotate between teams. Each team surveyed from only one sighting platform. On each observation platform there were three observing positions: port, center and starboard. Observers rotated among positions every 30 minutes, moving from the port to center to starboard observation position and then to a rest position which was not located on the observation platform. Every morning the starting position of the team members was chosen randomly with the constraints that the person in the first rest position rotated systematically and that the time spent in each observation position during the entire survey was approximately the same. Surveys were conducted when the Beaufort sea state was less than or equal to four and the visibility was greater than 500m.

To facilitate determining which groups of animals were detected by both teams, the observers tracked detected harbor porpoise groups, when possible, recording the position of two or three surfacings. The data collected for each marine mammal sighting included: time of sighting (recorded to the nearest second), species, radial distance between the ship and animal group (estimated visually), bearing angle between the ship's line of travel and the line of sight to the animal (measured with a polarus mounted in front of each observation position), group size (best, high and low estimates), direction the group was travelling initially (measured with the polarus), number of mother-calf pairs and sighting cue. The high (low) estimate of group size was defined as the largest (smallest) number of animals that was thought to be in the group. Best group size was defined to be the observer's judgement of most likely estimate of group size.

Data collected by the chief scientist at the beginning of each leg and the end of the day were: position (using LORAN C), ship's speed and bearing, position of each observer and environmental conditions including: wind speed and direction, swell direction and height, Beaufort sea state, presence of rain or fog, percentage of cloud cover, vertical and horizontal position of the sun and glare conditions for each observer as perceived by that observer. The latitude and longitude of each marine mammal sighting was estimated, after the survey, by dead reckoning between the positions recorded for the beginning and end of the leg in which the sightings was made in.

To obtain accurate visual estimates of radial distance between the ship and animal group, the observers were trained and tested. This was accomplished by having observers estimate the distance to a floating wooden replica of a harbor porpoise which was placed at various distances and bearings around the main ship. During the times the replica was being moved using a small boat, the observers, who were standing on their respective observation platform, were instructed not to look at the water. After the replica was placed in the water, the actual distance between the ship and replica was measured from the main ship to the small boat using the ship's radar. Then the small boat moved away

from the floating replica and the observers were instructed to find the replica, visually estimate the distance between the ship and replica and then use the polarus to measure the bearing. During training, the actual distance was immediately reported to the observers. During testing, actual distances were withheld until the end of the test. Training and testing occurred for one day before the survey and then during the survey for a few hours each week.

Analytical procedures

Two analytical techniques were used to estimate the abundance within each stratum and within the entire study area. Both techniques allow the estimation of $g(0)$. The first technique estimates $g(0)$ by the product integral method (Butterworth and Borchers, 1988) which assumes the sighting processes of the two teams are independent and consequentially the distribution of sightings detected by both teams (referred to as duplicate sightings) is predicted, not directly estimated. This assumption has often been necessary because of a small sample size of duplicate sightings. However, the sample size of duplicate sightings from this survey was large enough to permit the use of another technique that estimates abundance which is corrected for $g(0)$.

Using the first technique (product integral method), the abundance of animals ($\hat{N}$) was estimated by:

$$\hat{N} = \sum_{i=1}^{4} \hat{N}_i = \sum_{i=1}^{4} \hat{D}_i \,.\, A_i = \sum_{i=1}^{4} \frac{n_i.\hat{f}_i(0)}{2.L_i.\hat{g}_i(0)} \,.\, \hat{E}(s_i).A_i \tag{1}$$

where

N_i = estimated abundance of animals, corrected for $g(0)$, within stratum i;
$\hat{D}_i$ = estimated density of animals, corrected for $g(0)$, within stratum i;
n_i = number of unique sightings detected within stratum i;
= $n_{iup} + n_{ilo} - n_{idup}$;
n_{iup} = number of sightings detected by the upper team within stratum i;
n_{ilo} = number of sightings detected by the lower team within stratum i;
n_{idup} = number of sightings detected by both teams within stratum i;
$\hat{f}_i(0)$ = probability density of observed perpendicular distances from stratum i where the distance equals zero
L_i = length of trackline surveyed within stratum i;
$\hat{E}(s_i)$ = average size of porpoise groups detected within stratum i;
A_i = area of stratum i;
i = stratum index, i=1 to 4;
$\hat{g}_i(0)$ = probability of detecting an animal on the trackline within stratum i;
= $\hat{g}_{iup}(0) + \hat{g}_{ilo}(0) - [\hat{g}_{iup}(0) \,.\, \hat{g}_{ilo}(0)]$, where

$$\hat{g}_{iup}(0) = \frac{n_{idup}}{n_{ilo}} \,.\, \frac{\int_{y=0}^{w} \hat{g}_{ilo}(y)\, dy}{\int_{y=0}^{w} \hat{g}_{iuplo}(y)\, dy} \quad \text{and } \hat{g}_{ilo}(0) = \frac{n_{idup}}{n_{iup}} \,.\, \frac{\int_{y=0}^{w} \hat{g}_{iup}(y)\, dy}{\int_{y=0}^{w} \hat{g}_{iuplo}(y)\, dy} \tag{2}$$

and

$\hat{g}_{iup}(y)$ = probability of the upper team detecting a group at perpendicular distance y within stratum i;
$\hat{g}_{ilo}(y)$ = probability of the lower team detecting a group at perpendicular distance y within stratum i;

$\hat{g}_{iuplo}(y)$ = probability of both teams detecting a group at perpendicular distance y within stratum i;
w = maximum perpendicular distance.

Assuming the sighting processes of the two teams were independent, $\hat{g}_{iuplo}(y)$ was estimated by

$$\int_{y=0}^{w} \hat{g}_{iuplo}(y)\, dy = \int_{y=0}^{w} [\hat{g}_{iup}(y) \cdot \hat{g}_{ilo}(y)]dy \tag{3}$$

The value of $f_i(0)$ was estimated using the perpendicular distances of the unique sightings (n_i), where the perpendicular distance recorded by the first team that detected a duplicate sighting was used, regardless of which team made the detection.

The second technique used to estimate abundance, referred here to as the direct duplicate method, differs from the product integral method in that the independence assumption (equation 3) was not made. The animal density corrected for $g(0)$, within a stratum, ($\hat{D}_i$) was estimated directly from the Petersen two-sample mark-recapture equation. Thus, the abundance of animals, $\hat{N}$, was estimated by:

$$\hat{N} = \sum_{i=1}^{4} \hat{N}_i = \sum_{i=1}^{4} \hat{D}_i \cdot A_i = \sum_{i=1}^{4} \frac{\hat{D}_{iup} \cdot \hat{D}_{ilo}}{\hat{D}_{idup}} \cdot A_i \tag{4}$$

where
$\hat{D}_{iup}$ = density of animals as seen by the upper team, not corrected for $g(0)$;
$\hat{D}_{ilo}$ = density of animals as seen by the lower team, not corrected for g(0);
$\hat{D}_{idup}$ = density of animals detected by both teams, not corrected for g(0).

$\hat{D}_{iup}$, was estimated by

$$\hat{D}_{iup} = \frac{n_{iup} \cdot \hat{f}_{iup}(0) \cdot \hat{E}(s_{iup})}{2L_{iup}} \tag{5}$$

$\hat{D}_{ilo}$ and $\hat{D}_{idup}$ were estimated similarly. For comparison purposes, the value of $\hat{g}_i(0)$, under the direct duplicate method, was estimated using equation (2) and assuming $\hat{g}_{iuplo}$(y) (equation 3) was estimated from the observed perpendicular distances of the duplicate sightings.

Both the product integral and direct duplicate technique requires $\hat{E}(s_i)$, the estimated average group size. The observer's best estimates of group size were used. Several methods were used to determine if the probability of detecting a group of animals changed as a function of group size, referred to as size bias (Quinn, 1985; Drummer and McDonald, 1987). For the data collected within each stratum, a plot of group size versus perpendicular distance was inspected. If there was a significant slope, then size bias may exist. In addition, a covariate analysis was performed using the data from each stratum with the software package SIZTRAN (Drummer, 1991). In such an analysis, the probability of detecting a group ($g(y,s)$) is a bivariate function of both observed perpendicular distance, y, and group size, s, (Drummer and McDonald, 1987; Ramsey *et al.*, 1987). A bivariate detection function is described by the usual models (negative exponential, half normal, etc.) with an additional estimable parameter, α, which is defined as the effect of group size on the detection function. When α=0 no effect exists and there is no size bias. In a covariate analysis, the null hypothesis α=0 is tested using standard likelihood ratio tests. If the test is rejected, then size bias exists.

For both the product integral and direct duplicate technique, the hazard rate model was fit to unsmeared perpendicular distances, unless another model fit the data better, as was determined by the AIC score (Akaike Information Criteria; Akaike, 1974; Burnham *et al.*, 1987) and visual inspection of the fit near the origin, the most critical region

(Burnham *et al.*, 1980). The computer package DISTANCE (Laake *et al.*, 1991) was used to estimate $g(y)$, where the maximum perpendicular distance (w) was 400m. Using 400m, 8 and 9% of the sightings were deleted from the upper and lower team's data, respectively.

Equations (1) and (4) may represent an over-parameterised model. That is, some parameters within the equations may not differ between strata and, therefore, should not be estimated separately (Burnham *et al.*, 1987; Buckland and Turnock, 1992). To create a reduced, more parsimonious model, each parameter was investigated to determine if the values of the parameter from the high density, intermediate density and inshore stratum differ. The low density stratum had only three sightings and was, therefore, excluded from this test. Differences in $E(s_i)$ and n_i/L_i were investigated using Tukey's studentized range (HSD) multiple comparison test within an ANOVA framework (SAS Institute Inc., 1985). The Kolmogorov-Smirnov statistic (Zar, 1984) was used to determine if there were differences in the shape of the $\hat{g}(y)$ curves.

The estimate of $g(0)$, and consequentially the abundance, was dependent on which sightings were determined to be duplicates. Two people (D. Palka and D. Potter) independently categorized each sighting as a duplicate or non-duplicate sighting by examining the time the sighting was made, the location of the group in relationship to the ship, the direction of travel and the best, high and low estimate of group size. Duplicate sightings were rated as 'definite' or 'possible', depending on the confidence of the judgement.

Equations (1)-(5) were used to estimate abundance of porpoises within the high density and intermediate density strata. Because only three harbor porpoise groups were detected in the low density stratum, all by the lower team, the above equations had to be modified. The abundance estimate for the low density stratum was calculated assuming the detection function, $\hat{g}(0)$ and the average group size was the same in the low density as in the intermediate density stratum, while the values of n_i, L_i and A_i were those associated with the low density stratum.

The abundance within the inshore stratum used data collected aboard both the *R/V Abel-J* and *M/V Sneak Attack*. For this stratum, abundance was estimated by the product of three factors: (1) the $\hat{g}(0)$ corrected density of porpoises within the 5 n.mile strip of offshore waters, as determined by the *R/V Abel-J* survey, (2) the area of the shallow inshore stratum and (3) the ratio of the sighting rate of porpoise groups in inshore waters to the sighting rate in the 5 n.mile strip of offshore waters, as determined by the *M/V Sneak Attack* survey.

The variability of an abundance estimate for a stratum or for the whole study area is represented by the coefficient of variation (CV) and 95% confidence interval (CI). The variability is due to two components: (1) the usual sampling variability of parameters found in equations (1)-(5), given the number of duplicate sightings; and (2) the estimated number of duplicates which involves the uncertainties of categorizing a sighting as a duplicate or non-duplicate sighting (referred to as duplicate determination variability).

The sampling variability was estimated by using bootstrap re-sampling techniques (Efron, 1982). A bootstrap sample was generated by randomly selecting data, with replacement, from the original data. The re-sampling unit was a 'transect' of survey effort within a stratum (4–8 transects per day; 13–78 per stratum). Within a bootstrap sample, the number of transects in a stratum was constrained so that the total length of trackline within a stratum equals the trackline length in the actual survey. If after choosing a random transect, the trackline length exceeded the actual track length then only the first portion of the transect needed to reach the desired track length was used in that bootstrap sample. Because there were only three groups of porpoises detected in the low density stratum, the abundance of animals in the low density stratum within a bootstrap sample

was estimated as described above, except that n_{low} always equaled three (the actual number of groups observed in the low density stratum). The re-sampling procedure was repeated 1,000 times. Thus for each technique, 1,000 values for each stratum of all estimable parameters in equations (1) – (5) were created.

Assuming the two judges were a random sample from the set of possible competent judges, the duplicate determination variability was expressed by two sets of 1,000 bootstrap samples for each technique. One set was created assuming the duplicate sightings were those that were defined by Judge A and the other set assumed the duplicates were those defined by Judge B.

To obtain an estimate of both the sampling and duplicate determination variability of a parameter, the bootstrap distribution for that parameter using one judge's data was pooled with the respective bootstrap distribution from the other judge, resulting in a 'joint' distribution which contains 2,000 estimates of the parameter (Schweder *et al.*, 1991). This joint distribution estimates the sampling distribution of the parameter. The point estimate of the parameter was defined as the median of the corresponding joint bootstrap distribution. The endpoints of the 95% confidence interval of the parameter was estimated by the 2.5 and 97.5 percentile of the corresponding joint bootstrap distribution. The parameters in which this procedure was applied to was $g_i(0)$, $g_{iup}(0)$, $g_{ilo}(0)$, $g_{idup}(0)$, D_i and N_i. The point estimate of N was defined as the summation of the point estimates of N_i.

The CV of the total abundance [CV($\hat{N}$)] was calculated using

$$\mathrm{CV}^2\,(\hat{N}) = \hat{\mathrm{var}}(\hat{D}_T) \,/\, \hat{D}_T^2 \tag{6}$$

where

$$\hat{\mathrm{var}}(\hat{D}_T) = \sum_{i=1}^{4} \left(\frac{A_i}{A} \,.\, \mathrm{SE}(\hat{D}_i) \right)^2$$

$$\hat{D}_T = \sum_{i=1}^{4} \left(\frac{A_i}{A} \,.\, \hat{D}_i \right)$$

and

$\hat{D}_T$ = weighted total density of individuals within all strata;
A = area within all strata.

The SE($\hat{D}_i$) was estimated by the standard deviation (SD) of the 2,000 bootstrap estimates within the joint distribution of density of individuals from stratum i.

The percent coefficient of variation of $\hat{N}_i$ (%CV($\hat{N}_i$)) was estimated by:

$$\%\ \mathrm{CV}\ [\hat{N}_i] = \frac{\mathrm{SE}(\hat{N}_i)}{\hat{N}_I} \,.\, 100 \tag{7}$$

where the SE of $\hat{N}_i$ equals the SD of the bootstrap $\hat{N}_i$ estimates within the joint distribution and $\hat{N}_i$ is the point estimate of the joint distribution from stratum i.

RESULTS

Sneak Attack survey

The *M/V Sneak Attack* travelled 640 n.miles in four geographic areas each of which was divided into the shallow inshore stratum and adjacent offshore five-mile area (Fig. 3). A total of 135 harbor porpoise groups were detected (Table 1). The mean number of sightings per seven mile transect was 1.66 and the mean best estimate of group size was 1.91. There were no significant differences (p=0.28) between the number of porpoise

Table 1

Summary of results from the *M/V Sneak Attack* sighting survey in four geographical areas (A,B,C,D). Each geographical area was divided into an inshore and offshore area. The reported results are track length measured in n.miles, area (n.miles^2), number of detected harbor porpoise groups, number of sightings per number of 7 n.mile transects (sighting rate), number of completed transects and average size of detected groups.

	Area	Track length	Area	No. of groups	Sighting rate (*N*)	Av. group size
A	Inshore	174	350	49	2.09 (23)	1.67
	Offshore	50	100	11	1.38 (8)	1.82
B	Inshore	86	175	25	2.00 (12)	1.64
	Offshore	42	85	9	1.17 (6)	1.56
C	Inshore	64	125	22	2.44 (9)	2.50
	Offshore	51	100	8	1.14 (7)	2.12
D	Inshore	74	150	1	0.17 (6)	2.00
	Offshore	99	200	10	1.25 (8)	2.70
All	Inshore	398	800	97	1.90 (50)	1.85
	Offshore	242	485	38	1.24 (29)	2.05
Total		640	1285	135	1.66 (79)	1.91

sightings per transect in the inshore (1.90, SD=2.23, N=50) and offshore (1.24, SD=1.45, N=29) areas, nor were there significant differences (p=0.89) between the mean group size in the inshore (1.85, SD=1.37, N=97) and offshore (2.05, SD=1.39, N=38) areas (Read and Kraus, 1991). The ratio of the sighting rate of porpoise groups in the inshore stratum to the sighting rate in the offshore five-mile area was 1.53. The value of this ratio was used in the inshore stratum abundance estimate (see below).

***Abel-J* survey**

The *R/V Abel-J* covered approximately 1,961.5 n.miles of trackline in the study area during good weather conditions (Fig. 4; Table 2). In addition, 73.5 n.miles were covered during a bad weather (poor visibility) day; 82.5 n.miles were covered in the inshore bays of Nova Scotia (not in the study area) using both the *R/V Abel-J* and a rigid hulled inflatable 17-foot boat (*Zodiac*[1]); 40.25 n.miles were traveled in Passamaquoddy Bay, Maine (not in the study area) using the *Zodiac*[1]. In total, the trackline length was 2157.8 n.miles.

The data collected during the bad weather day were excluded.

The upper team saw 499 harbor porpoise groups, of which 27 groups were excluded because three had missing data and 24 were made during the bad weather day. This resulted in 472 good sightings detected by the upper team (Fig. 5; Table 2). The lower team saw 391 harbor porpoise groups, of which 16 groups were excluded because they were made on the bad weather day. This resulted in 375 good sightings detected by the lower team (Fig. 5; Table 2). One group of harbor porpoises was detected in the inshore bays of Nova Scotia, another was detected in Passamaquoddy Bay, Maine. These two sightings were not used in the analysis.

The best estimate of $E(s)$ was determined to be the arithmetic mean, $\bar{s}$, because size bias was not significant. This is illustrated by the fact that the slope between group size and

[1] Mention of trade names does not constitute endorsement by NMFS.

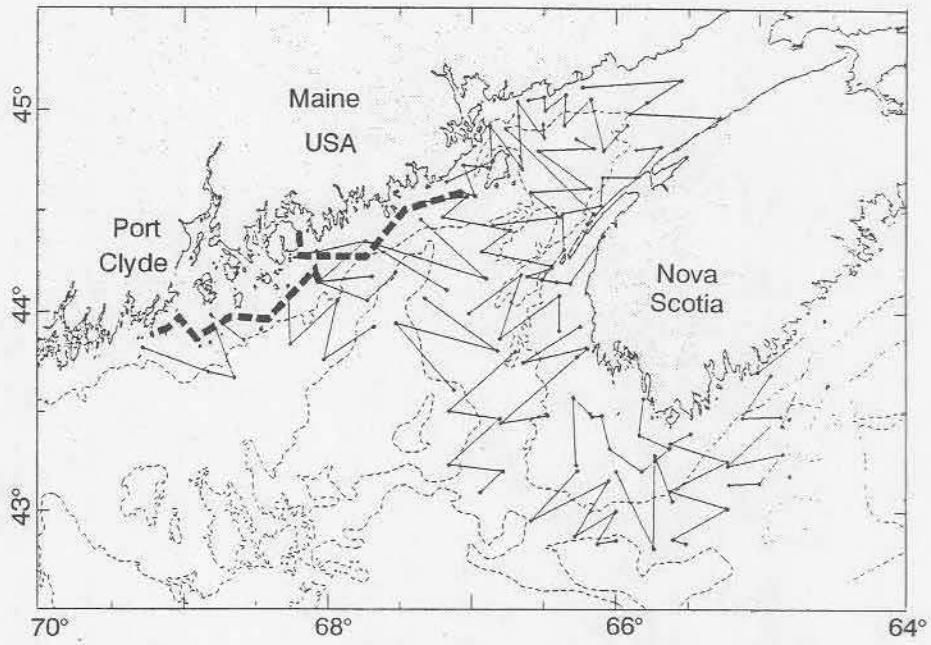

Fig. 4. Tracklines surveyed by the *R/V Abel-J*. Heavy dashed line are tracklines within the 5 n.mile offshore area. Other tracklines are within the high density, intermediate density and low density stratum.

Table 2

Summary of results from the *R/V Abel-J* line transect survey in four strata: high density (High), intermediate density (Interm.), low density (Low) and inshore (Inshore). The reported results are length of trackline in n.miles (% of total length in parentheses), area of stratum in n.miles^2 (% of total area in parentheses), total number of groups detected by the upper and lower teams, (number of groups within a perpendicular distance of 400m from the trackline in parentheses), average size of groups within 400m (%CV in parentheses).

			Number of groups		Av. (%CV) of group size	
Strata	Track length (%)	Area (%)	Upper	Lower	Upper	Lower
High	310 (0.16)	1,552 (0.11)	236 (217)	203 (184)	2.97 (3.9)	2.99 (7.3)
Interm.	1,333 (0.68)	9,038 (0.65)	216 (197)	149 (144)	2.76 (4.2)	2.38 (5.5)
Low	189 (0.10)	2,674 (0.19)	0 (0)	3 (3)	0 -	2.00 (0.5)
Inshore	130 (0.07)	637 (0.05)	20 (19)	20 (17)	4.26 (15.5)	3.29 (14.9)
Total	1,962 (1)	13,901 (1)	472 (433)	375 (345)	2.93 (2.9)	2.75 (4.8)

perpendicular distance, as recorded by the upper team was not significant, (H_0: slope=0 for all strata together, p=0.36). However, the lower team's estimates of group size decreased slightly as perpendicular distance increased (H_0: slope=0 for all strata together, p=0.04). The effect of group size (α in a bivariate model) was not significant for every combination of team and stratum, given the negative exponential, half normal and general exponential model, i.e., there was no obvious group size bias (Table 3).

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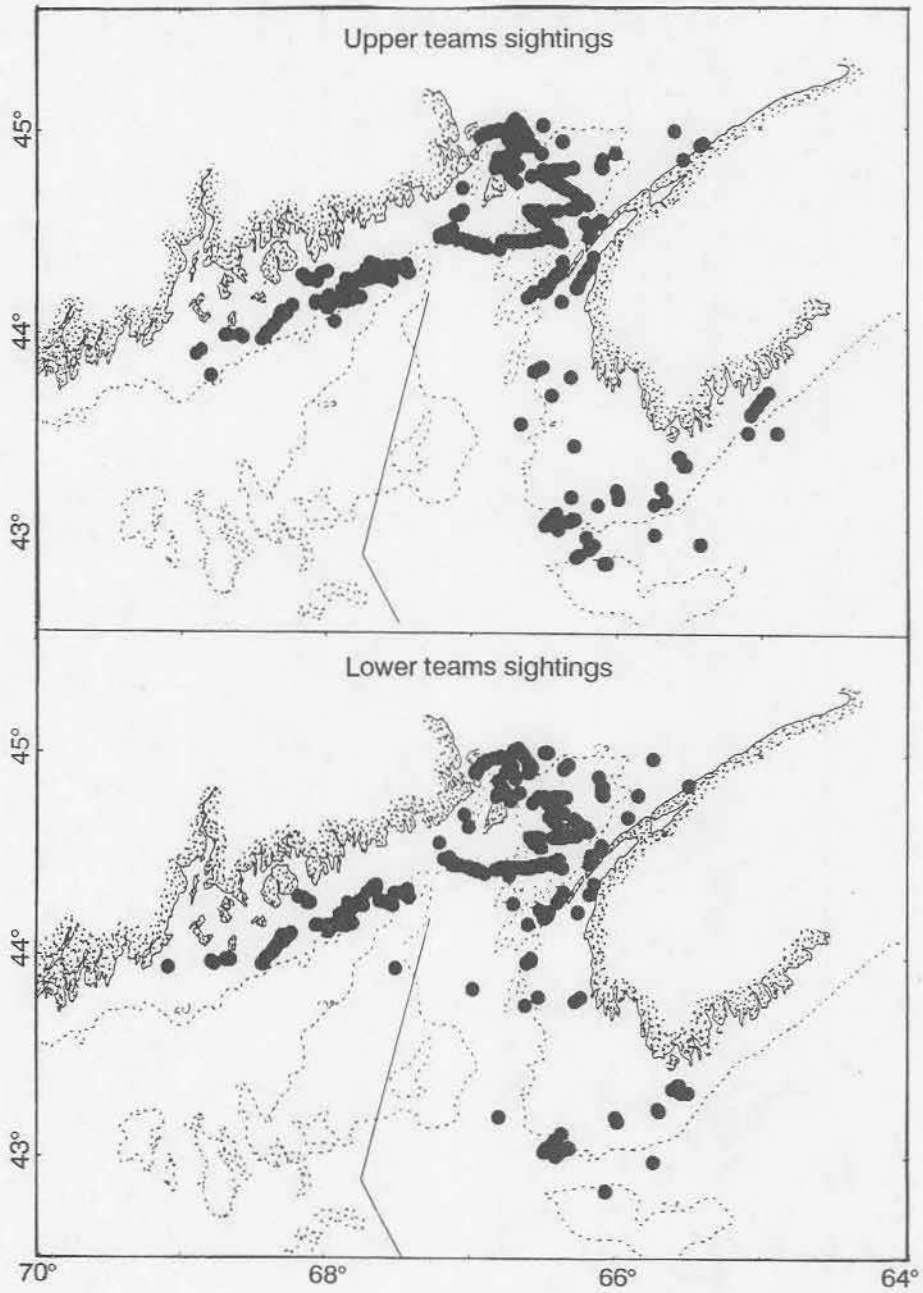

Fig. 5. Location of harbor porpoise groups that were detected by the upper and lower team aboard the *R/V Abel-J*. Solid line through center of area represents the US – Canadian border.

Table 3

The bivariate models that were investigated are negative exponential, half normal and general exponential. Results from each model include the value of α, which reflects the effect of group size ($\alpha=0$ indicates no group size effect), *p*-value from the test $H_0:\alpha=0$ vs $H_1:\alpha\neq0$, Akaike information criteria (AIC) and estimated density of schools. * indicates the least AIC value, which represents the best model that fits the data. ◂ indicates the model (bivariate or univariate) that resulted in the greater school density estimate.

Model	Model	α	*p*-value	AIC	School density
Upper team - high density stratum					
Negative exponential	bivariate	-0.024	0.274	-599.72	3.723◂
	univariate	-	-	-601.70*	3.707
Half normal	bivariate	-0.041	0.310	-617.54	2.345◂
	univariate	-	-	-619.45*	2.344
General exponential	bivariate	-0.008	0.261	-617.20	2.615
	univariate	-	-	-618.75*	2.643◂
Upper team - intermediate density stratum					
Negative exponential	bivariate	-0.369	0.496	-568.17*	0.839◂
	univariate	-	-	-564.22	0.813
Half normal	bivariate	-0.353	0.500	-588.74*	0.533◂
	univariate	-	-	-580.07	0.514
General exponential	bivariate	-0.380	0.500	-587.45*	0.580◂
	univariate	-	-	-578.84	0.579
Upper team - inshore stratum					
Negative exponential	bivariate	-0.189	0.321	-60.18	1.041◂
	univariate	-	-	-62.03*	0.984
Half normal	bivariate	-0.150	0.315	-60.76	0.640◂
	univariate	-	-	-62.65*	0.613
General exponential	bivariate	-0.216	0.333	-59.13	0.760
	univariate	-	-	-61.00*	0.780◂
Lower team - high density stratum					
Negative exponential	bivariate	-0.041	0.207	-515.11	3.201◂
	univariate	-	-	-517.06*	3.185
Half normal	bivariate	-0.048	0.243	-545.47	2.092◂
	univariate	-	-	-547.47*	2.092
General exponential	bivariate	-0.060	0.164	-545.81	2.142◂
	univariate	-	-	-548.43*	2.124
Lower team - intermediate density stratum					
Negative exponential	bivariate	-0.283	0.474	-434.22*	0.667◂
	univariate	-	-	-433.54	0.651
Half normal	bivariate	-0.319	0.497	-447.97*	0.425◂
	univariate	-	-	-443.22	0.411
General exponential	bivariate	-0.318	0.495	-446.62*	0.470
	univariate	-	-	-441.31	0.474◂
Lower team - inshore stratum					
Negative exponential	bivariate	+0.148	0.204	-51.60	0.839◂
	univariate	-	-	-53.50*	0.795
Half normal	bivariate	+0.358	0.109	-52.68	0.527◂
	univariate	-	-	-54.09*	0.495
General exponential	bivariate	+0.301	0.142	-50.74	0.604
	univariate	-	-	-52.34*	0.628◂

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To determine the best reduced, stratified model [equations (1) and (4)], the estimates of group size and encounter rate, along with the shape of the estimated detection functions were compared between strata. The average group size (± 1SD) as estimated by the upper and lower team was 2.93 ±1.75 and 2.75 ±2.46, respectively (Table 2). Mean group sizes did not differ significantly between teams (HSD critical value=2.78; SAS Institute Inc., 1985). Mean group size from the intermediate density stratum (upper: 2.76; lower:2.38)

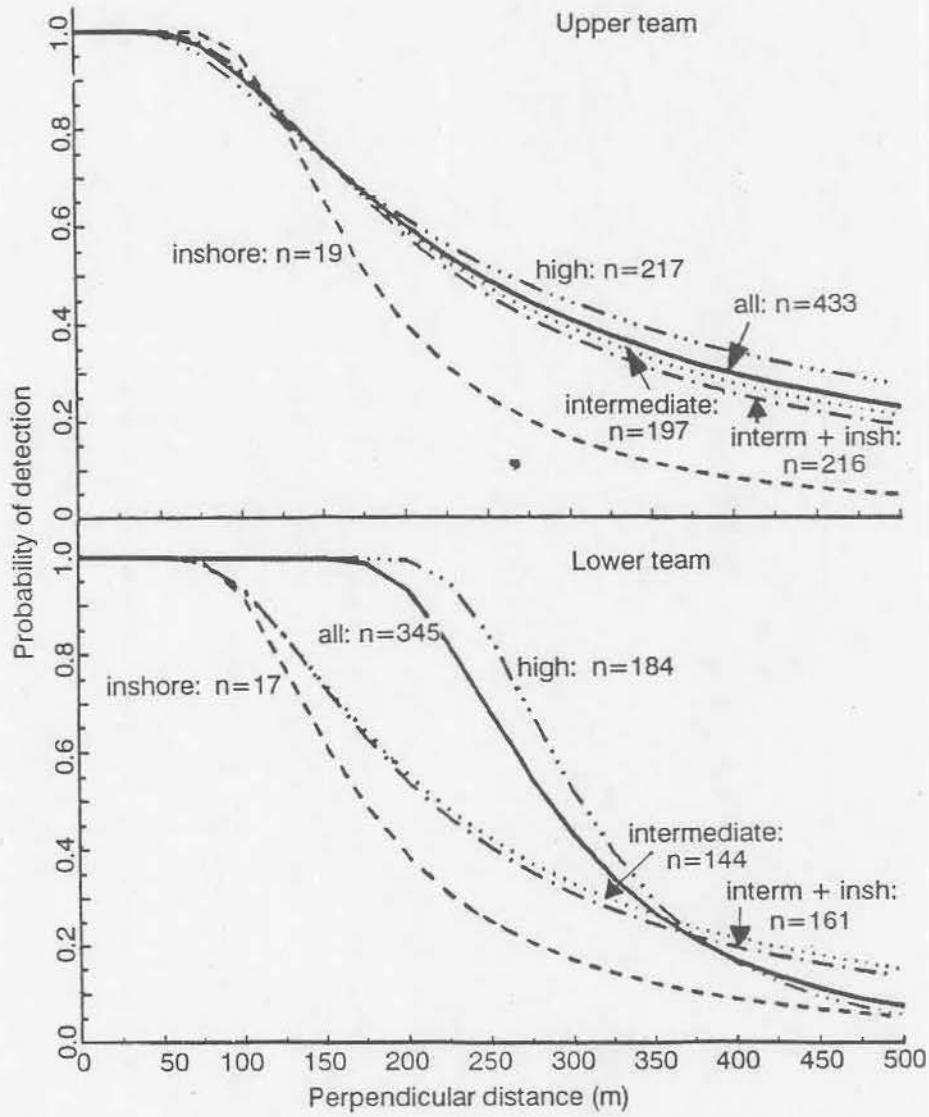

Fig. 6. Detection functions estimated from data collected within the high density, intermediate density and inshore strata by the upper and lower team members (high, intermediate and inshore). In addition, the detection function estimated from data pooled over all strata is displayed (all).

was statistically different than that from either the high density (upper:2.97; lower:2.99) or inshore stratum (upper:4.26; lower:3.29) (HSD critical value 3.32). The encounter rate (n_i/L_i) from the high density stratum (upper:0.76 groups per n.miles; lower:0.66) was statistically different than either the inshore (upper:0.15; lower:0.15) or intermediate density stratum (upper:0.16; lower:0.11) (HSD critical value=3.337). Within a team, there were no significant differences between estimated detection functions for any of the strata (Fig. 6; for all pairwise comparisons within a team the Kolmogorov-Smirnov D value was greater than the critical value for that pair). Thus, the preferred reduced stratified model is where $f(0)$ is estimated from data pooled over strata and the other parameters are estimated by strata.

The number of 'definite' duplicate sightings as determined by Judge A and B was 113 and 138, respectively, while the number of 'possible' duplicates were 54 and 8, respectively (Table 4). The sum of definite and possible duplicate sightings as determined by Judge A and B was 167 and 146, respectively. Using the weighing scheme suggested in Butterworth and Borchers (1988) i.e. sum the number of definite duplicates and 2/3 of the possible duplicates, the resulting numbers of duplicates were 149 (Judge A) and 143 (Judge B). Of the number of harbor porpoise groups detected by the upper team, 35% and 31% of the groups were categorized as either a definite or possible duplicate sighting by Judge A and B, respectively (Table 5).

Table 4

Number of duplicate sightings within three strata (high density, intermediate density and inshore) as determined by two judges (A=Palka, B=Potter). The duplicates were categorized as definitely a duplicate (Definite) or possibly a duplicate (Possible). Definite + Possible is sum of definite and possible duplicates. A weighted number of duplicates is the sum of definite duplicates and 2/3 of the possible duplicates (Definite + 2/3 Possible).

	Definite		Possible		Definite + Possible		Definite + 2/3 Possible	
Stratum	A	B	A	B	A	B	A	B
High	60	71	30	6	90	77	80	75
Intermediate	46	60	22	2	68	62	61	61
Inshore	7	7	2	0	9	7	8	7
Total	113	138	54	8	167	146	149	143

Table 5

Ratio of number of duplicate sightings to number of sightings detected by the upper team. Definition of headings in Table 4.

	Definite		Possible		Definite + Possible		Definite + 2/3 Possible	
Stratum	A	B	A	B	A	B	A	B
High	0.25	0.30	0.13	0.02	0.38	0.33	0.33	0.32
Intermediate	0.21	0.28	0.10	0.01	0.31	0.29	0.28	0.28
Inshore	0.35	0.35	0.10	0.00	0.45	0.35	0.40	0.35
Total	0.24	0.29	0.11	0.02	0.35	0.31	0.32	0.30

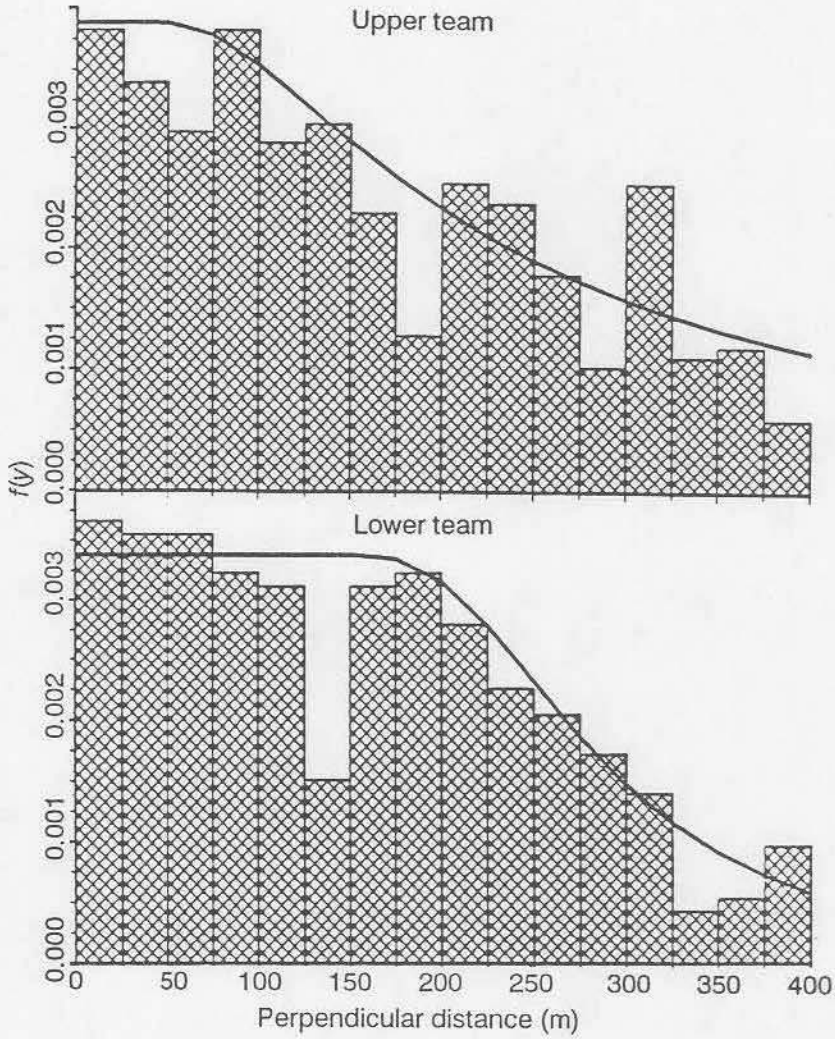

Fig. 7. A histogram of perpendicular distances from all strata that were detected by the upper and lower team is overlaid by the estimated hazard rate detection function.

The strategy of categorizing a duplicate differed between the two judges. Judge A had more stringent criteria for a definite duplicate and looser criteria for a possible duplicate. Of the 138 sightings categorized as a definite duplicate by Judge B, 92 (67%) were categorized as a definite duplicate by Judge A and 122 (88%) were categorized as either a definite or possible duplicate by Judge A (Table 6). However, of the 54 possible duplicates as categorized by Judge A, 20 (37%) were categorized as a non-duplicate sighting by Judge B (Table 6). After both judges reviewed these sightings, it was agreed upon that the criteria used by Judge A to assign a sighting as a possible duplicate was too loose. Therefore, for the rest of this analysis, only the definite duplicate sightings will be used.

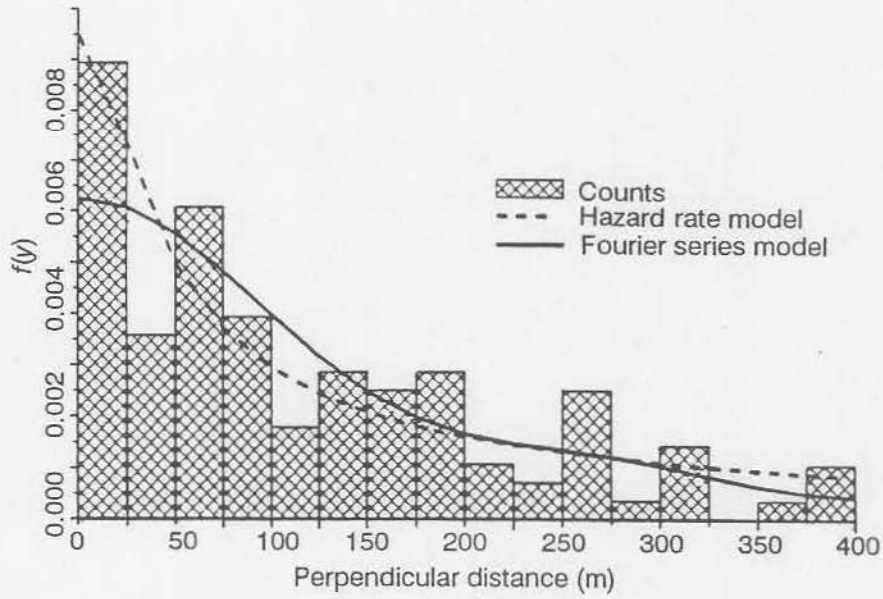

Fig. 8. Comparison of the estimated hazard rate and third order Fourier detection function overlaying a histogram of the observed perpendicular distances of the duplicate sightings as defined by Judge A.

The hazard rate model fitted the perpendicular distance data well (Fig. 7), with the exception of the distance data from the duplicate sightings as assigned by Judge A (Fig. 8). Because of a peak in the perpendicular distances at the origin (near the trackline), a third order Fourier model fit better than did the hazard rate model (Fig. 8), as was noted in Buckland (1985). Therefore, in the bootstrap iterations used to estimate variance, a third order Fourier model was used to fit only the bootstrap duplicate data from Judge A; the hazard rate model was used elsewhere.

The estimated effective half strip width (ESW) for the upper and lower teams was 258m (SE=16.4) and 296m (SE=44.1), respectively (Table 7). This difference is not significant (z=0.81; p=0.42). No significant difference was found between the ESW estimated from

Table 6

Comparison of duplicate classification of each individual sighting that was declared a Definite or Possible duplicate sighting by either of the two judges. If a sighting was declared as a duplicate by a judge but not by the other then that sighting was classified as a non-duplicate according to the latter judge.

		Judge A			
		Definite	Possible	Non-duplicate	Total
Judge B	Definite	92	30	16	138
	Possible	3	4	1	8
	Non-duplicate	18	20	x	39
	Total	113	54	17	185

Table 7

Effective strip half-width (ESW) in meters and its standard error as estimated from data pooled over strata for each team (Upper only and Lower only), for the duplicate sightings as predicted by the product integral method (Upper - Lower) and for duplicate sightings as estimated from the duplicates which were determined by either judge.

Data source	ESW	SE(ESW)	Data source	ESW	SE(ESW)
Upper only	257.7	16.4	Dups only - Judge A	160.3	20.2
Lower only	295.8	44.1	Dups only - Judge B	204.9	24.0
Upper - Lower	260.6	25.8			

the duplicate sightings as determined by Judge A (160m; SE=20.2) and those determined by Judge B (205m; SE=24.0) (z=1.42; p=0.16). The ESW of the duplicate sightings as predicted by the product integral method ($\hat{g}_{up}(y)\cdot\hat{g}_{lo}(y)$) was 261m (SE=25.8) (Table 7).

The point estimates of $g(0)$ for the upper team within the various strata were higher than the corresponding $g(0)$ from the lower team's data (upper: 0.46 to 0.62; lower: 0.33 to 0.52; Table 8), though the differences were not significant (pairwise z-tests). The point estimate of $g_i(0)$ as estimated by the direct duplicate method (range: 0.71–0.82) was slightly higher than that estimated by the product integral method (range: 0.65–0.75) (Table 9), though the difference between the differences are not significant. An area weighted average of $g(0)$ estimated by the product integral and direct duplicate method was 0.66 (SE=0.07)

Table 8

Estimates of $g_{iup}(0)$ and $g_{ilo}(0)$ as determined by the product integral method and direct duplicate method, where i is the high density, intermediate density, low density and inshore stratum.

		Product integral		Direct duplicate				Product integral		Direct duplicate	
Stratum	Team	$g(0)$	SE(g)	$g(0)$	SE(g)	Stratum	Team	$g(0)$	SE(g)	$g(0)$	SE(g)
High	Upper	0.46	0.06	0.53	0.10	Low	Upper	0.46	0.09	0.53	0.11
	Lower	0.37	0.09	0.43	0.06		Lower	0.33	0.10	0.38	0.07
Interm.	Upper	0.46	0.09	0.53	0.11	Inshore	Upper	0.53	0.13	0.62	0.18
	Lower	0.33	0.10	0.38	0.07		Lower	0.45	0.18	0.52	0.17

Table 9

Estimates of $g_i(0)$ as determined by the product integral method (PI) and direct duplicate method (DD), where i is the high density, intermediate density, low density and inshore stratum. In addition, the area weighted average $g(0)$ is presented.

Stratum	Method	$g(0)$	SE($g(0)$)	Strata	Method	$g(0)$	SE($g(0)$)
High	PI	0.66	0.07	Inshore	PI	0.75	0.14
	DD	0.73	0.07		DD	0.82	0.15
Intermediate	PI	0.65	0.10	Average	PI	0.66	0.07
	DD	0.71	0.09		DD	0.72	0.06
Low	PI	0.65	0.10				
	DD	0.71	0.09				

Table 10

Using either the product integral or direct duplicate method, the following results are presented: estimated density (animals per nmi^2) where $g(0)=1$ (uncorrected density) and its standard error (SE), estimated density including an estimate for $g(0)$ (corrected density) and its standard error and estimated abundance with its standard error and coefficient of variation.

Stratum	Uncorrected density (SE)	Corrected density (SE)	Abundance	SE(N)	CV(N)
Product integral method					
High	10.3 (2.60)	15.6 (3.85)	24,287	5,976	0.25
Intermediate	1.8 (0.50)	2.9 (0.70)	25,820	6,331	0.25
Low	0.15 (0.01)	0.23 (0.04)	616	96	0.16
Inshore	4.2 (1.46)	5.7 (2.36)	3,603	1,506	0.42
Direct duplicate method					
High	3.8 (1.14)	10.9 (5.71)	16,900	8,862	0.52
Intermediate	0.6 (0.22)	1.9 (0.70)	16,944	6,340	0.37
Low	0.15 (0.01)	0.23 (0.04)	616	96	0.16
Inshore	2.0 (1.09)	4.8 (2.29)	3,023	1,459	0.48

and 0.72 (SE=0.06), respectively. This average $\hat{g}(0)$ is the best overall estimate of $g(0)$ for this survey.

The estimated density within the high density stratum was substantially higher than any other stratum (Table 10). The density within the inshore stratum was the next highest, while the density within the low density stratum was the lowest. The product integral technique resulted in higher density estimates than did the direct duplicate method (Table 10), though the differences were not significant (high: $z=0.68$ $p=0.50$; intermediate: $z=1.01$ $p=0.31$; inshore: $z=0.27$ $p=0.28$).

The abundance estimated for the high density and intermediate density strata were similar (Table 10), despite the large difference in strata areas. The product integral abundance point estimates for each stratum was larger than the direct duplicate abundance point estimate for the corresponding stratum, although the differences were insignificant. Total abundance estimates were 37,500 (CV=28.8%) with a 95% CI of (26,600 to 86,400) and 54,300 (CV=16.3%) with a 95% CI of (38,100 to 71,900), as determined from the direct duplicate and product integral techniques, respectively (Table 11). The difference between the total abundance estimates from the two techniques was not significant ($z=1.21$; $p=0.23$).

Table 11

The abundance of each stratum and the entire survey area as estimated by the product integral or direct duplicate method. Also included is the coefficient of variation and upper and lower 95% confidence limits (UCL and LCL) as estimated using bootstrap resampling techniques.

	Abundance (%CV)	LCL	UCL	Abundance (%CV)	LCL	UCL
	Product integral method			**Direct duplicate method**		
High	24,287(0.25)	11,975	34,878	16,900 (0.52)	8,572	45,597
Intermediate	25,820(0.25)	15,082	39,167	16,944 (0.37)	10,702	36,097
Low	616(0.16)	451	804	616 (0.16)	451	804
Inshore	3,603(0.42)	1,308	7,320	3,023 (0.51)	1,239	6,712
Total	54,326(0.16)	38,140	71,930	37,483 (0.29)	26,643	86,369

DISCUSSION

The abundance estimate presented here is larger than previous estimates, largely due to the greater survey area. In addition, most of the previous estimates did not include an estimate of $g(0)$. The estimate of $g(0)$ made from the present dataset (0.72) is similar to that estimated by Barlow (1988) for harbor porpoises (0.78), who also used the two independent team sighting procedure. However, the present estimate of $g(0)$ is larger than the estimate of $g(0)$ for northeastern Atlantic minke whales (0.51; Schweder *et al.*, 1992). Minke whales are also difficult to detect, have no obvious blow and are usually found in small groups. The estimate of $g(0)$ for minke whales was made using the parallel ship sighting procedure and a different analysis procedure.

Of the two techniques to estimate abundance that were presented here, the direct duplicate method is the preferred technique. Both techniques assume the two teams are independent. However, the direct duplicate method uses a weaker version of the assumption. That is, the product integral method predicts the distribution of duplicate sightings to be the product of $g_{up}(y)$ and $g_{lo}(y)$, as estimated separately from data from each platform. The direct duplicate method does not predict the distribution of the duplicate sightings, but directly estimates the distribution from the duplicate sighting's data. As was discussed in Butterworth and Borchers (1988) and Schweder (1990), the independence assumption (equation 3) may not be valid, even on a theoretical basis. Schweder (1990) suggested that this is because some factors may not act independently to the sighting processes of the two teams and therefore, the two teams are conditionally dependent. The two teams in this survey may be conditionally dependent as is evident by the fact that the product integral method predicted more duplicate sightings near the trackline than that observed from the actual duplicate sightings (Fig. 9). This phenomenon was also noted in Butterworth and Borchers (1988). In conclusion, because the direct duplicate method does not explicitly use the independence assumption it is the preferred method. The disadvantage of the direct duplicate method is that a large number of duplicate sightings are required (>40; Burnham *et al.*, 1980) to accurately estimate the $g_{dup}(y)$ distribution.

The estimates presented here have substantial uncertainty, as reflected in the relatively large CV of 28.8%. The largest component of this variation is the encounter rate (n/L; Table 12). By definition, the CV(n/L) should only include sampling variation. However, practically, the CV(n/L) includes both sampling variation and variation in the spatial distribution of the animals. The encounter rate does have spatial structure; i.e. there is evidence of a density gradient related to ocean depth (Fig. 5). Other analysis methods are needed to properly account for this spatial variability, for example, Schweder (1977) and Thompson (1991).

Table 12

Coefficient of variation of various parameters in the density equation. Also, the percentage of the CV of a parameter with respect to the CV of the density when $g(0)$ is assumed to equal one. Estimates are for the high density, intermediate density and inshore stratum, using data from each team.

Parameter	CV	%	CV	%	CV	%	Parameter	CV	%	CV	%	CV	%
Upper team							**Lower team**						
n/L	21.4	75.1	21.3	76.9	31.0	52.8	n/L	22.1	86.5	24.0	78.9	26.9	45.8
$f(0)$	11.7	22.4	10.9	20.1	24.8	33.9	$f(0)$	4.8	4.1	11.1	16.9	25.2	40.2
s	3.9	2.5	4.2	3.0	15.5	13.3	s	7.3	9.4	5.5	4.2	14.9	14.0
D	24.7	100	24.3	100	42.6	100	D	23.7	100	27.0	100	39.8	100

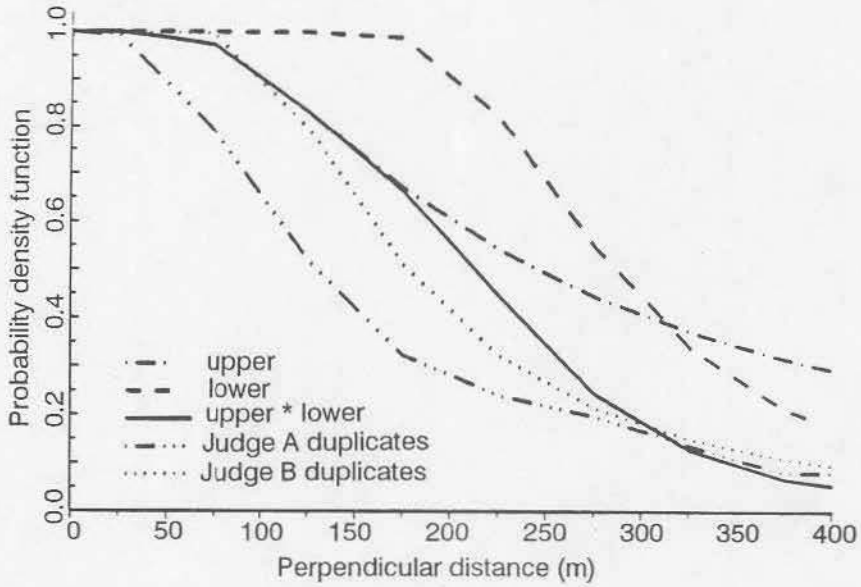

Fig. 9. Comparison of the distribution of duplicate sightings as predicted by the product integral method (upper*lower) and as estimated from the observed perpendicular distances of duplicate sightings which were determined by either Judge A or Judge B. For reference, the distribution of perpendicular distances estimated from the data collected by the upper and lower teams are also displayed.

In addition to the spatial structure in the encounter rate, there are several other possible sources of uncertainty unaccounted for in this study. These sources include incomplete coverage of the animals' range, porpoise avoidance of the ship, observer and/or platform heterogeneity and effects of other environmental conditions on sighting rates and $g(0)$. The boundaries of the study area were selected on the basis of previous sighting data. Sighting surveys were performed from a *Zodiac*[1] and the *R/V Abel-J* in coastal southeastern Nova Scotia and Passamaquoddy Bay, Maine, both regions not included in the survey area. During these surveys two porpoise groups were detected in 131 n.miles of searching. This sighting rate is much lower than that observed during the *M/V Sneak Attack* survey, also in coastal waters. Also, one group of harbor porpoises was reported south of the southern boundary along the Maine coast by the survey team on the *M/V Sneak Attack* (Read and Kraus, 1991). Overall, the spatial distribution of the observed sightings suggest that the *a priori* boundaries nearly reflect the actual boundaries.

It has been suggested that harbor porpoises avoid ships (Gaskin, 1977; Kraus *et al.*, 1983b; Polacheck and Thorpe, 1990). If porpoises alter their behavior before being detected by observers on the ship, then the abundance estimate will be biased (Turnock and Quinn, 1991). In the future, the distance at which the porpoises start altering their behavior should be demonstrated to determine if, and to what extent, the abundance estimate is biased.

Buckland (1992) illustrated that heterogeneities have effects on the abundance estimate. During the present survey it is possible there were heterogeneities between the platforms. This means the relative efficiency of the two platforms may have varied with environmental or other factors (Buckland, 1992). This could be illustrated by the fact that

$g_{up}(0)$ was greater than $g_{lo}(0)$, though the difference was not significant (Table 8). The effect of this heterogeneity on the abundance estimate is unknown. An investigation into whether this and other heterogeneities exist may be feasible because some of the necessary data have already been collected during this survey.

Factors other than perpendicular distance may influence the shape of the detection function and consequentially the abundance estimate. Examples of possible influential factors are group size (Drummer and McDonald, 1987) and Beaufort sea state (Gunnlaugsson and Sigurjónsson, 1990). Not including such factors will result in an incorrect abundance estimate. In this study, group size was determined not to be influential (Table 3). Beaufort sea state information was also collected during this survey. Incorporating Beaufort sea state into the bivariate detection functions in SIZTRAN (Drummer, 1991) resulted in the conclusion that Beaufort sea state was not an influential factor, despite the fact that the sighting rate decreased as Beaufort sea state increased. The same conclusion was reached by Gunnlaugsson and Sigurjónsson (1990). Possible explanations for this contradiction are that the line transect technique is robust to the amount of variability that occurs within the range of Beaufort sea state 0 to 3 or possibly the Beaufort sea state scale is not representative of the overall environmental conditions, which actually does influence the detection function.

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Abundance Estimate of the Gulf of Maine Harbor Porpoise

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ABSTRACT

Shipboard surveys were conducted in the summer of 1991 to estimate the abundance of harbor porpoises, *Phocoena phocoena*, in the northern Gulf of Maine and lower Bay of Fundy. The best estimate is 37,500 (95% CI: 26,600 to 86,400). The estimate is based on the independent team sighting procedure from one ship, which allowed the estimation of $g(0)$: 0.72 (SE=0.06). The abundance estimate presented is substantially higher than previous estimates for the area. This is due to the more extensive areal coverage and the inclusion of $g(0)$ into the estimate. While the statistical precision that was reported here included some sources of uncertainty, others remain to be addressed. The most important of these are the potential downward bias due to animals avoiding the vessel, the highly aggregated spatial distribution of porpoises and the largely unknown effects of heterogeneity of observers, platforms and environmental conditions.

KEYWORDS: HARBOUR PORPOISE; NORTH ATLANTIC; SURVEY-SHIP; ASSESSMENT; $g(0)$.

INTRODUCTION

There are five past surveys that estimated the abundance of harbor porpoise in the Gulf of Maine-Bay of Fundy region (Gaskin, 1977; Prescott *et al.*, 1981; Winn, 1982; Kraus *et al.*, 1983b; Gaskin *et al.*, 1985). Estimates ranged from roughly 3,000 to 15,000 animals. They provided minimum estimates of abundance because of their limited ranges and because of failures of assumptions made in the analyses. In 1991, two surveys were conducted over a much broader area using line transect survey techniques developed to overcome some of the previous methodological problems (Kraus *et al.*, 1983a; Barlow, 1988; Butterworth and Borchers, 1988; Polacheck, 1989; 1994a; b; Polacheck and Smith, 1989; 1990; Øien, 1990; Polacheck and Thorpe, 1990; Polacheck *et al.*, 1990; 1994).

In this paper, I present a new population abundance estimate using data collected during the two 1991 surveys. The reliability of the abundance estimate is assessed and potential sources of uncertainties that were not accounted for are discussed. This paper updates the abundance estimate reported in Smith *et al.* (1991), Anon. (1992) and Read *et al.* (1993).

METHODS

Field procedures

From 22 July – 31 August 1991, a shipboard sighting survey was performed in the offshore waters of the Gulf of Maine-lower Bay of Fundy-southern Scotian shelf area. From 3 – 17 August 1991 a second survey was performed in the shallow inshore bays off Maine (Fig. 1). 'Passing mode' line transect methods (Burnham *et al.*, 1980; Butterworth and Borchers, 1988) were used on both vessels. The independent team sighting procedure was used on

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REPORT

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Evaluating the use of roving diver and transect surveys to assess the coral reef fish assemblage off southeastern Hispaniola

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Abstract The relatively little-studied fish fauna off southeastern Hispaniola was rapidly assessed using a combination of visual survey techniques including transects and roving diver surveys. It was found that when combined, both methods provided a more complete overall species assessment than either method was able to provide in isolation. Being able to conduct rapid species assessments is becoming increasingly more important as a conservation tool. Data on species composition, sighting frequency, and abundance of all fishes were collected using both methods. Abundance was recorded in four logarithmic-based categories (roving diver method) while the number of fishes were counted within 40-m^2 transects (transect method). Both methods were similar in recording the most abundant species, while a greater number of rare species (especially fishery-targeted species) were recorded with the roving diver method. The most abundant groupers were *Cephalopholis cruentata* and *C. fulva*. The most abundant parrotfishes were *Scarus taeniopterus*, *Sparisoma aurofrenatum*, and *Scarus iserti*. The most conspicuous differences between fishes off southeastern Hispaniola and elsewhere in the tropical western Atlantic were the low abundance and smaller size of harvested species such as groupers, snappers (Fam. Lutjanidae), and grunts (Fam. Haemulidae). With the roving diver method, more time could be spent surveying (instead of placing transect lines), resulting in a greater number of species being recorded. Additionally, well-trained volunteers can adopt the roving diver method as part of their regular diving program. Transect surveys were able to provide information such as length (biomass) and actual density measures that were not recorded in roving diver surveys. Thus, these methods were complementary and should be used in conjunction when conducting rapid assessments of fish assemblages, especially to detect the effects of overfishing.

Keywords Fish assemblages · Survey methods · Hispaniola · Dominican Republic · Conservation · Coral reefs

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Introduction

Fishes are a conspicuous element of coral reef ecosystems in the tropical western Atlantic (Starck 1968; Bohlke and Chaplin 1993), and are often a focus of monitoring and management programs to evaluate the condition of reef communities (Hatcher et al. 1989). When the species composition, abundance, or size distribution of fish assemblages changes, this is often an indication of additional underlying ecological change on the reef (Reese 1977; Hughes 1996). Assessing variables such as species composition, sighting frequency, density, and length frequency distributions allows the characterization of a particular fish assemblage in space and time. When compared among regional locations, these characteristics, especially for fisheries-targeted species, can be monitored for changes from baseline values, and effects of various management strategies can be evaluated (Bohnsack 1982; McClanahan 1994; Jennings 1995). In this way, biological surveys and assessments of key reef taxa groups such as fishes are essential to management and conservation efforts (Goldsmith 1991; Pattengill-Semmens 1998).

Historically, fish inventories were carried out via the comprehensive but destructive technique of poisoning a given area of the reef (Randall 1963; Starck 1968). However, destructive methods cannot be repeated in the same area and result in the death of many fishes as well as other organisms. Visual surveys are repeatable and especially valuable since they minimize the impact of sampling on the environment. Visual surveys are highly effective in the clear water present on most coral reefs, but have the tendency to overlook or underestimate the abundance of cryptic reef fishes (DeMartini and Roberts 1982; Bortone 1991). Diurnally active species are reasonably well censused, but the most common species are often underestimated; nocturnal species are more difficult to survey due to restricted visibility (Brock 1982). For all visual surveys, fish sizes tend to be overestimated. However, this can be corrected with training and corrections for bias in length estimates (Bell et al. 1985; St. John et al. 1990). Transects have been traditionally used as one of the standard visual survey methods and the biases in this technique have been well studied (Brock 1954; Sale and Sharp 1983; Fowler 1987; Watson et al. 1995; Cheal and Thompson 1997; Sale 1997; and others). However, with the need for fish survey monitoring data to be conducted rapidly and at low cost, trained volunteer surveyors using the roving diver technique (RDT) are being increasingly employed (Pattengill-Semmens and Semmens 1998; Pattengill-Semmens 2001). In this study, we surveyed the relatively little studied fish fauna off southeastern Hispaniola using the transect and roving diver visual survey techniques. We compared the data generated by both methods. The results of this study should be useful in the continued monitoring of fishes in southeastern Hispaniola in an area where commercial fisheries collapsed in the early 1970s (Towle et al. 1973; Secretaria de Estado de Agricultura 1994; Vega et al. 1996) It is also hoped that this information will assist in the rapid assessment of fishes on reefs in other areas to document the effects of fishing and to assist in the development of more comprehensive management plans (Hatcher et al. 1989; Wilcox et al. 1989; MAMMA 1998).

Methods

Fishes were surveyed using both the transect and roving diver methods at four reef sites in southeastern Hispaniola listed in order from north to south: Dominicus, La Raya, Rubén, and El Toro (Fig. 1). The more northern reef sites are closer to tourist areas (Bayahibe) and coastal cities such as La Romana. The most northern site examined, Dominicus, occurs just north of the boundary of Parque Nacional del Este (PNE), and offshore of a resort. The three other reef sites examined are offshore of the uninhabited coast of the Park along the western shore of southeastern Hispaniola. El Toro is both the southernmost and most exposed site off the southwestern shore of Isla Saona. The reef habitat at La Raya consists of deep rocky outcroppings and small, elevated patches separated by sand at a depth of 16–18 m. The reef habitats at Dominicus and Rubén are characteristic low-relief spur-and-groove systems (Shinn et al. 1977, 1981), at a depth of 15–17 and 18–20 m, respectively. El Toro is a low-relief, hard-bottom habitat with relatively little vertical relief at a depth of 16–18 m. All four

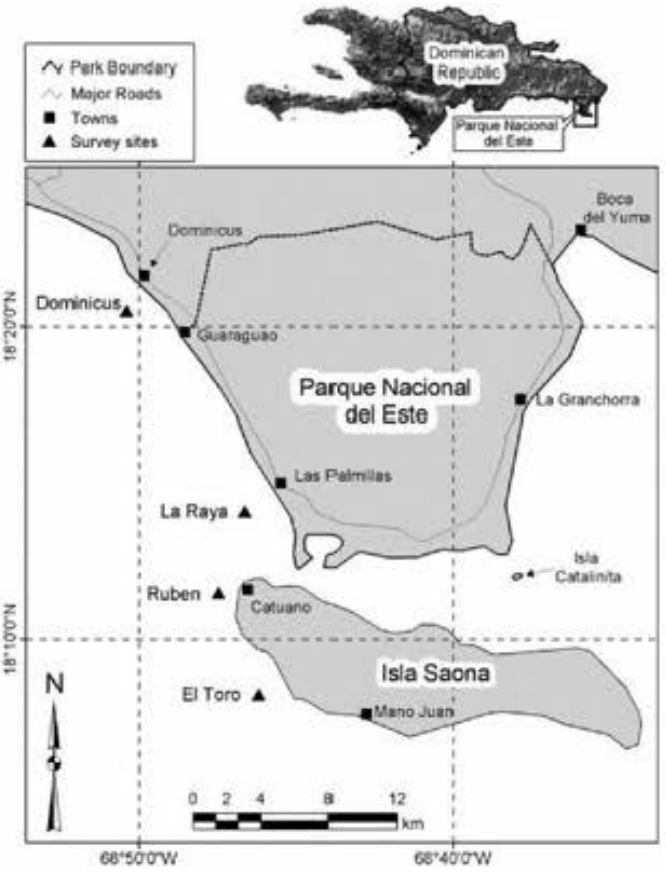

Fig. 1. Fish survey sites off southeastern Hispaniola. The boundaries of Parque Nacional del Este (PNE) are indicated. (Illustration by Brian K. Walker, National Coral Reef Institute, Dania Beach, Florida)

sites have a similar depth range (15–20 m), vertical relief measured by the chain transect method, where values indicate the amount of chain overlain on the surface to cover a flat distance of 100 cm (119–129 cm/m), sediment cover (11.0–32.8%), algal cover (52.2–70.0%), sponge cover (4.6–15.2%), hard coral cover (5.2–20.2%), and octocoral cover (0.40–3.4%) as measured by percent composition of benthos within 20 (1-m^2) quadrats at each reef site (Table 1). Transect and roving diver surveys were conducted at each site and pooled from all sites in order to rapidly assess the overall fish assemblage structure and compare data gathered by the roving diver method with the transect method.

Survey methods

The transect method involved recording the presence and abundance of all fish species as well as their length (estimated to the nearest centimeter) present in a 40-m^2 strip transect (20 m long by 2 m wide). Observers were trained to estimate fish lengths by using models both on land and underwater. The distribution of each observer's estimated model sizes was compared to the known size distribution using a χ^2 test. The training exercise was continued until there was no significant difference between the observer's estimated size distribution and the known distribution (Bell et al. 1985). Transect widths were visually estimated and divers (using SCUBA) surveyed as they set the transect line to minimize disturbance to fishes (Fowler 1987). Transects were placed along the rocky outcroppings and spurs present at each reef site. Sighting frequency was determined as the number of times a species was observed divided by the total number of surveys (transects). A maximum of only one sighting of each species was possible per

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A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers

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Abstract

An inexpensive towed video camera sled was developed to provide abundance estimates for juvenile flatfishes and other benthic taxa, and to characterize habitat features. The camera sled was compared with beam trawls and diver survey methods in Yaquina Bay, Oregon, and in bays of Kodiak Island, Alaska. In Yaquina Bay the camera sled with a tickler chain (to induce flatfish movement) yielded density estimates for juvenile flatfish (English sole, *Pleuronectes vetulus*) that were equivalent to those of the divers, but greater than with a 1 m beam trawl or the camera sled without a tickler chain. Crab (*Cancer magister*) density estimates were similar between the divers and the camera sled (with or without the tickler chain), but were underestimated with the beam trawl. In Kodiak, densities of juvenile flatfish (northern rock sole, *Lepidopsetta polyxystra*) were similar between the camera sled with a tickler chain, divers, and a 2 m beam trawl. Density estimates from the camera sled were obtainable for flatfish as small as 20 mm. Habitat features, such as empty bivalve shells, were underestimated with the beam trawl compared with the divers and the camera sled. These results demonstrate the effectiveness of an inexpensive, simple to operate, towed camera sled in surveying abundance and habitat associations of juvenile flatfishes, crabs, and other taxa.
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Keywords: survey technique; video; fish; habitat

1. Introduction

Effective methods for surveying demersal fish distributions and abundance are critical for assessing changes in populations, community structure, and recruitment patterns. Trawls are the traditional gear used to survey demersal fishes, and small (1–3 m) beam trawls have been the preferred gear for juvenile flatfishes (Kuipers, 1975; Gunderson and Ellis, 1986; Kuipers et al., 1992; Rozas and Minello, 1997). However, trawl collections underestimate fish density (Wennhage et al., 1997; Munro and Somerton, 2002) and provide little information on habitat characteristics and complexity. In contrast, divers can count fish directly and document habitat associations. While diver surveys have been conducted primarily for reef fish studies, Walton and Bartoo (1976) recognized the potential advantages of visual transects in sand bottom habitats, and developed a flatfish sampler that could be used by divers to rake fish out of the sediment for counting and size estimation. However, divers remain limited by depth and time restrictions.

Increasingly, underwater camera systems mounted on submersibles, remotely operated vehicles (ROVs), and towed platforms or sleds have been developed to view fishes in their associated habitats and to obtain

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a permanent record of the survey area (Uzmann et al., 1977; Felley et al., 1989; Lough et al., 1989; Adams et al., 1995; Gregory and Anderson, 1997; Diaz et al., 2003). Norcross and Mueter (1999) adapted ROVs for use in locating juvenile flatfishes by attaching tickler chains to induce flatfish movement. While the ROVs proved effective for estimating juvenile flatfish densities and characterizing habitat types, these systems are expensive and require special training to maintain and operate.

Development of better and more easily accessible methods for assessing distribution of juvenile flatfish and other cryptic demersal species is necessary for improved identification of essential habitat and better understanding of recruitment-related processes. The objective of this study was to develop and test an inexpensive underwater camera sled, suitable for deployment from a small boat, and compare its utility, relative to diver and beam-trawl surveys, in quantifying the abundance of economically important juvenile flatfishes, crabs, and habitat features.

2. Materials and methods

2.1. Study sites

Survey comparisons were conducted in August, 2002, at five sites in Yaquina Bay, Oregon, a known nursery for English sole (*Pleuronectes vetulus*) (Boehlert and Mundy, 1987; Rooper et al., 2003), and at four sites in two embayments along the northeast coast of Kodiak Island, Alaska, which provide nurseries for northern rock sole (*Lepidopsetta polyxystra*) (Norcross et al., 1997). At each site, one transect line was positioned in an area of low bottom relief with sand/mud substrate, and the length and orientation of each transect were selected to minimize changes in habitat characteristics while maximizing distances for gear comparisons and numbers of flatfish observed. In Yaquina Bay (44°37′ N, 124°02′ W) transect lines were 30 m in length and were oriented parallel to the depth contour. Bottom temperatures ranged from 9.4 to 12.2 °C and depths ranged from 3 to 5 m. The Yaquina sites were located inshore from the dredged channel of the bay, but were subject to moderate flow (~ 50 cm s^{-1}) during maximum tidal current. Two of the Kodiak sites were located off Holiday Beach (57°41′ N, 152°27′ W) in Middle Bay and two were in Pillar Creek Cove (57°49′ N, 152°25′ W) in Monashka Bay. At Holiday Beach, transect lines were 100 m in length and oriented parallel to the depth contour. At Pillar Creek Cove, transects lines were 200 m in length and were perpendicular to the depth contour. Bottom temperatures at the Kodiak sites ranged from 8.3 to 10.0 °C. At Holiday Beach, depths ranged from 12 to 13 m, while at Pillar Creek Cove they ranged from 5 to 15 m. There was minimal current (<10 cm s^{-1}) at the Kodiak sites.

2.2. Survey gear and approach

A 5.2 m skiff was used to deploy gear in Yaquina Bay, and the 9.1 m charter boat F/V *Miss O* was used in Kodiak. At each site a transect line was anchored tautly on the bottom and marked at the ends with surface floats. This provided for boat and diver orientation. The survey techniques were conducted at each transect in a rapid sequence ordered by increasing impact on the substratum and fish community: divers, camera sled without tickler chain (Yaquina Bay sites only), camera sled with tickler chain, and beam trawl. This approach was justified by preliminary observations made by divers that juvenile flatfish and Dungeness crabs moved only short distances (typically <2 m) upon disturbance. Furthermore, there was minimal overlap in the narrow paths (≤ 1 m) travelled by the camera sled and divers. To reduce possible effects of tidal current on species abundance and composition, all surveys were conducted at a site within 2 h of high tide in the Yaquina Bay, with the exception of one site when the use of the towed gear was delayed until 5 h after the high slack tide. This precaution was deemed unnecessary for the Kodiak Island sites, where tidal currents were minimal; however, the survey sequence was completed within 2 h at each location.

The camera sled (Fig. 1) was fabricated with 3.8 cm diameter aluminium pipe (sled dimensions: $L=114.3$ cm, $W=67.3$ cm, $H=41.9$ cm). Aluminium flanges ($L=29$ cm, $W=4$ cm), with holes drilled every 3.7 cm, welded to the top front of the frame allowed the attachment points of the bridle to be adjustable for better balance of the sled as depth and scope changed. Four lead-weights (1.36 kg each) taped to the lower sled frame ensured solid contact with the bottom. After results from the Yaquina Bay comparisons showed that estimates of flatfish density were significantly lower when the camera sled was not equipped with a tickler chain, it was tested only with a tickler chain at the

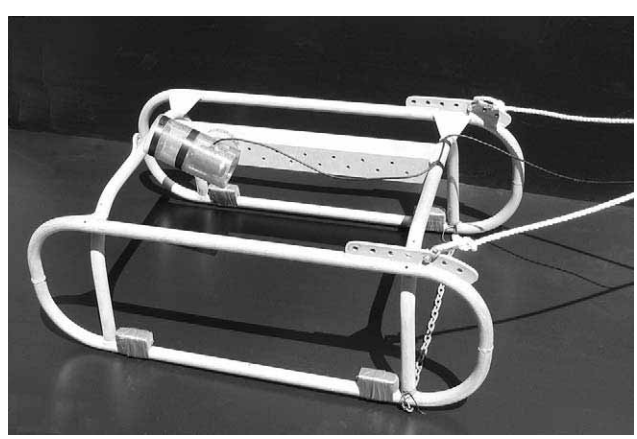

Fig. 1. Camera sled with tickler chain.

Kodiak sites. The tickler chain (2.5 cm diameter links, galvanized steel) was attached with twine to the front vertical struts. This provided a weak link in the event of striking an obstruction. The total weight of the camera sled with the camera and weights was 19 kg.

The underwater camera was an Aqua-Vu ZT-120 (Nature Vision, Inc, Brainerd, MN) equipped with a temperature sensor and 37 m long cable leading to a small black-and-white monitor on deck. The video image with temperature stamp was captured with a Sony digital video camera recorder (DCR-PC110) for later analysis. The camera housing was a 23 cm length of clear acrylic pipe (10 cm diameter). The housing was mounted on an aluminium beam ($L=76$ cm, $W=7.6$ cm) running lengthwise between the top horizontal struts of the sled. Holes drilled at 7.5 cm intervals along the beam enabled forward/aft adjustment of the camera. The vertical angle of the camera was adjusted by rotating the camera housing against the beam. For the surveys described in this paper, the camera lens was positioned 55 cm from the front vertical struts where the tickler chain was attached and set at an angle of 35° from horizontal; this positioning maximized the field of view while keeping the tickler chain, when present, visible at the bottom of the image. This provided a maximum forward view of 3.2 m. This oblique view was 0.67 m wide at its base and 2.5 m at the top. The total field of view was 5.0 m^2. However, juvenile flatfishes were predominately encountered directly in front of the tickler chain where the width of view was 0.67 m, so counts were confined to this swath and this width was used as the effective gear width. The cost of fabricating the camera sled and outfitting it with the underwater camera was approximately US$2000.

The camera sled was deployed by hand at one end of each transect line and towed (60 cm s^{-1}, average speed) along one side of the transect line to the opposite endpoint. This was immediately followed by a tow along the other side of the transect line. Flatfishes observed in each video record were counted. The smallest flatfish that could be counted with certainty were ≥ 20 mm total length (TL), as estimated by comparison with the known dimensions of the links in the tickler chain. This was similar to the smallest flatfish consistently observed by the divers and captured in the beam trawls. In Yaquina Bay few large flatfish were observed and all juvenile flatfish were combined for analysis. Like English sole, Dungeness crabs (*Cancer magister*) utilize northeastern Pacific estuaries as nursery grounds (Stevens and Armstrong, 1984; Gunderson et al., 1990; Stone and O'Clair, 2001), and were abundant in certain locations in Yaquina Bay. Therefore, counts were also made for Dungeness crabs. This provided another economically important taxon for comparison of survey techniques. In Kodiak, the flatfish were divided into two size classes, <60 and >80 mm TL, which represent age-0 and age-1+ rock sole, respectively, based upon length–frequency distributions in August (Hurst and Abookire, unpublished data). Although accurate length measurements were not possible with the camera and diver survey methods, they were not required for age class distinctions because of obvious size separation (e.g. mean TL of age-0 = 42 mm, age-1+ = 97 mm in August, 2004, Hurst and Abookire, unpublished data). Empty bivalve shells were consistently present at the Kodiak sites. Survivorship of juvenile rock sole is enhanced by selectively utilizing habitat with emergent structure, including shell (Stoner and Titgen, 2003; Ryer et al., 2004). Therefore, empty bivalve shells >5 cm diameter were quantified along with the fish.

For the diver counts, two divers swam simultaneously along either side of the transect line, pushing a 1 m length of 2 cm PVC pipe over the sediment surface to gauge transect width and to induce movement of flatfish out of the sediment. Care was taken not to double-count flatfish or crabs that moved from one side of the transect line to the other, or moved ahead and resettled along the transect line. Divers stopped to record counts at 3 m intervals along the 30 m transects, at 5 m intervals along the 100 m transects, and at 25 m intervals along the 200 m transects. This gave divers opportunity to record counts without the risk of missing fish while making notes. Intervals were increased with increased transect length to ensure timely completion of the transect. Swimming speed of the divers was 5–10 cm s^{-1}.

In Yaquina Bay, a 1 m beam trawl (1.0 m effective fishing width, 3 mm mesh codend, 3 mm mesh net body) with a single tickler chain positioned 20 cm in front of the trawl footrope was used (modified from Kuipers, 1975). A 2 m plumb-staff beam trawl (1.8 m effective fishing width, 3 mm mesh codend, 10 mm mesh net body) with a single tickler chain positioned 20 cm in front of the footrope was used in Kodiak (modified from Gunderson and Ellis, 1986). Average towing speed was 60 cm s^{-1}. Two tows were conducted consecutively along either side of a transect line. English sole comprised 95% of the flatfish counts in Yaquina Bay beam trawls, and northern rock sole were 95% of the flatfish catch in Kodiak.

2.3. Statistical analysis

For each site, the two counts for each survey technique from a transect line were considered non-independent samples due to their proximity, and averaged to increase accuracies of estimates made with each gear type. Each value was then standardized to count per 100 m^2 based upon the effective width of the gear (divers = 100 cm, camera sled = 67 cm, 1 m beam trawl = 100 cm, 2 m beam trawl = 180 cm) and transect length (Yaquina = 30 m, Kodiak = 100 or 200 m). Data

were log-transformed to achieve homogeneity of variance and analyzed among sites within each location using an unreplicated two-way analysis of variance (ANOVA) (Sokal and Rohlf, 1981). Where significant differences occurred ($p<0.05$), post-hoc multiple comparisons (Tukey HSD) were performed (Zar, 1984).

3. Results

In Yaquina Bay, density estimates of juvenile flatfishes made with the camera sled with a tickler chain were generally equivalent to, or exceeded those made with the other survey methods (Table 1, Fig. 2a). Juvenile flatfish densities estimated from the tickler chain-equipped camera sled were comparable to those from the diver surveys, and both of these were greater than density estimates produced by the chainless-sled surveys (Tukey HSD, $p<0.05$). In addition, density estimates from the tickler chain-equipped camera sled were greater than those made from the 1 m beam trawl. There were also differences among survey methods for estimates of crab densities in Yaquina Bay (Table 1, Fig. 2b). Crab estimates were similar between the divers and the camera sled, both with and without a tickler, while estimates from all three were significantly greater than those from the 1 m beam trawl (Tukey HSD, $p<0.05$, Fig. 2b). Site differences in densities occurred only in the crab density estimates (Table 1).

At the Kodiak Island sites, density estimates from the divers, the tickler chain-equipped camera sled, and the 2 m beam trawl were similar for both age-0 and age-1+ flatfishes (Table 1, Fig. 3a,b). However, the survey methods yielded significant differences in shell density estimates (Table 1, Fig. 3c). The diver and the camera sled surveys produced higher shell densities than the beam trawl (Tukey HSD, $p<0.05$). Significant differences in densities among sites were found for age 1+ flatfish and shells (Table 1). The largest shells included horse clams (*Tresus capax*) and surf clams (*Mactromeris polynyma*).

Table 1
Results from two-way ANOVA on log-transformed density estimates comparing survey types by site

	df	SS	MS	*F*	*p*
Yaquina Bay					
Flatfish					
Survey type	3	20.39	6.80	10.81	0.001
Site	4	2.09	0.52	0.83	0.531
Survey type×site	12	7.54	0.63		
Crabs					
Survey type	3	14.82	4.94	9.14	0.002
Site	4	13.77	3.44	6.37	0.006
Survey type×site	12	6.49	0.54		
Kodiak					
Age-0 flatfish					
Survey type	2	0.57	0.28	1.81	0.242
Site	3	1.21	0.40	2.57	0.150
Survey type×site	6	0.94	0.16		
Age-1+ flatfish					
Survey type	2	0.02	0.01	0.08	0.926
Site	3	2.52	0.84	7.99	0.016
Survey type×site	6	0.63	0.11		
Shells					
Survey type	2	5.44	2.72	39.63	0.000
Site	3	11.76	3.92	57.11	0.000
Survey type×site	6	0.41	0.07		

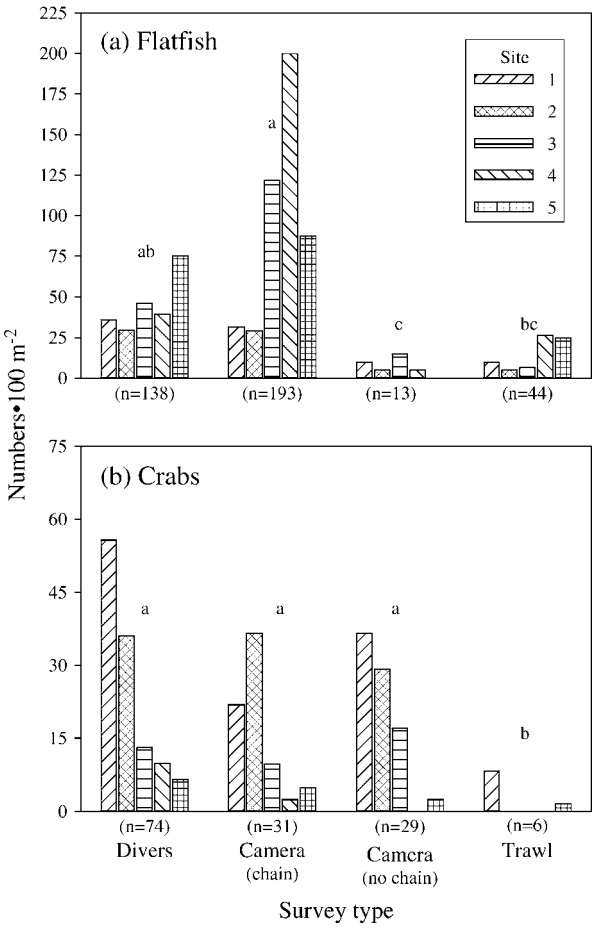

Fig. 2. Densities of juvenile flatfish (a) and crabs (b) at five sites in Yaquina Bay, Oregon as estimated by divers, camera sled without and with tickler chain, and 1 m beam trawl. Estimates were calculated by standardizing the actual number counted (*n*) along each transect to number 100 m^{-2} based on the width of the gear and the actual length of each transect. Estimates for survey types with the same letter were not significantly different based on Tukey multiple comparison tests following two-way ANOVAs without replication.

4. Discussion

The camera sled developed and tested in this study was inexpensive, simple to operate, and proved to be a very effective means for surveying juvenile flatfishes, Dungeness crabs, and their habitats. Flatfishes as small

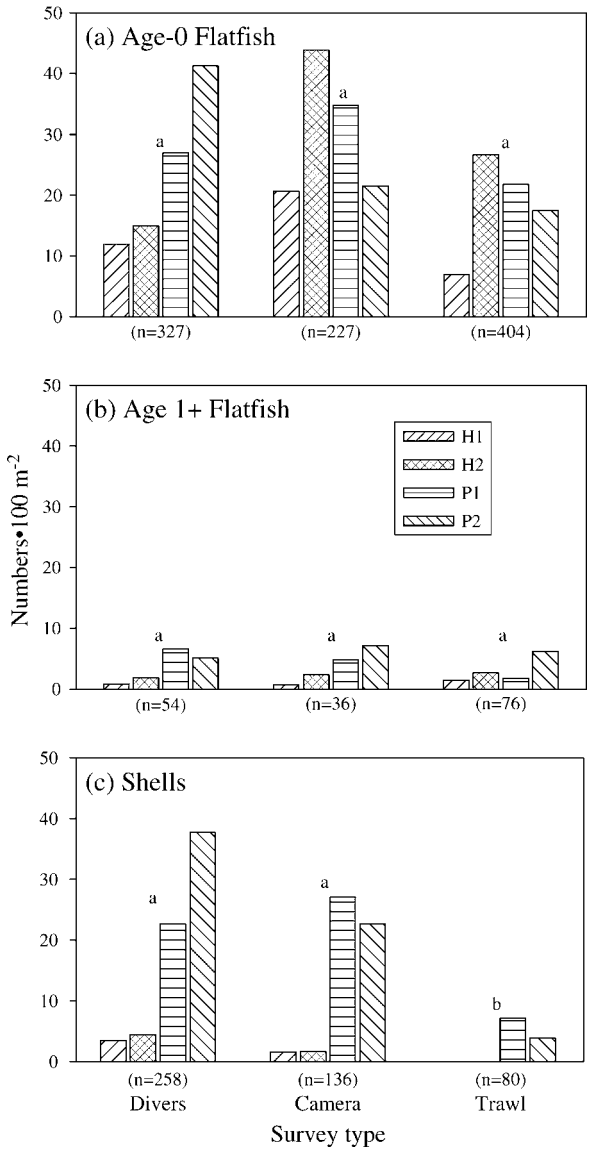

Fig. 3. Density of age-0 flatfish (a), age 1+ flatfish (b), and empty bivalve shells (c) at two sites along Holiday Beach (H1, H2) and at two sites in Pillar Creek Cove (P1, P2), along the coast of Kodiak Island, Alaska, as estimated by divers, camera sled with tickler chain, and 2 m beam trawl. Estimates were calculated by standardizing the actual number counted (n) along each transect to number 100 m^{-2} based on the width of the gear and the actual length of each transect. Estimates for survey types with the same letter were not significantly different based on Tukey multiple comparison tests following two-way ANOVAs without replication.

as 20 mm TL were well quantified when a tickler chain was used in camera view, equalling or exceeding the performance of divers and beam trawls. Larger flatfishes (>80 mm TL) and crabs could be surveyed effectively with or without a tickler chain. Other fishes, seastars, hermit crabs, jellyfish, shrimps, anemones, and sea pens could be quantified from video tapes. The camera sled was non-destructive to mobile organisms, and the sled's runners and tickler chain caused little damage to substrate and sessile invertebrates.

The key advantages of the camera sled compared with other survey methods investigated in this study were the accuracy of flatfish quantification made possible by replaying videotapes at slow speed, combined with the efficiency of a towed gear system that requires limited deployment time and has unrestricted tow duration. While other studies (e.g. Thresher and Gunn, 1986; Fowler, 1987; Cheal and Thompson, 1997; Samoilys and Carlos, 2000), along with ours, show that diver surveys can provide good estimates for fish density, limitations and sources of error include diver experience (Kulbicki and Sarramégna, 1999), variations in diver swim speed (Lincoln Smith, 1988; Watson et al., 1995), and time and depth restrictions. None of these are concerns with a towed camera. However, accurate identification of small flatfish species is difficult with camera sled and diver surveys, making lack of collections the main weakness of these methods. There was also a risk of counting the same fish more than once for both the camera sled and divers. However, the video recording from the camera sled facilitated tracking fish locations, thereby decreasing this risk. Although the forward view of a diver was potentially greater than that of the fixed camera, it was effectively similar since the diver needed to consistently limit attention to the area directly ahead of the tool used to disturb the flatfish.

Environmental conditions limiting accuracy of density estimates for a towed camera system are bottom roughness, natural light, and turbidity. Other types of towed underwater camera systems have been designed for manoeuvrability over high-relief bottoms (e.g. Goeden, 1981; Barker et al., 1999), but they are more complicated to operate and not well-suited for locating and quantifying cryptic or burying species. For this study, natural light was sufficient for viewing the bottom, and lights could easily be attached to the camera sled for surveys at greater depth. Water turbidity can be a larger problem in visual surveys, both with cameras or divers. However, in this study, the fishes of primary interest were observed directly in front of the tickler chain, and turbidity was not a severe problem until horizontal visibility fell below about 30 cm.

Camera sled performance was observed in various habitat types in Yaquina Bay and near Kodiak. While the camera sled performed best on low-relief sand or mud substrata, it was also capable of negotiating biogenic depressions, sand waves, and cobbles. The tickler chain lost contact with the substratum in areas with high vertical relief (>30 cm) created by sea cucumber mounds (*Paracaudina chilensis*), but subsequent modifications of the tickler chain by adding additional lengths of chains dangling from the main chain helped to correct this problem. The sled system could be used without a tickler chain on cobble bottom, on hard bottom with relatively low relief, and in short seagrass, but not in more rugged terrain or stands of

kelp. A tickler chain would not be necessary for quantifying large, mobile, and non-cryptic taxa, such as age-1+ flatfishes and crabs, and for dedicated habitat studies.

While all of the gear types compared in this study were easily deployed from a small boat, they differed in their efficiencies for covering large areas and their complexity of use. Divers can count fish accurately and can record bottom features with either written notes or a video camera; however, diving is costly in terms of both time and effort. Also, divers are limited to small areas of survey coverage because of bottom time and depth restrictions, whereas beam trawls and the camera sled can be towed for long periods of time, and at depths limited only by the amount of tow rope or cable that can be handled. We have used the camera sled successfully to 35 m depth with a longer cable in clear water. Our towed camera system can be deployed quickly and easily by one person, and can be used to cover extensive areas of the bottom. However, analysis of videotape can be time consuming, depending upon the amount of information being extracted.

Despite the time needed for analysis, videotapes from camera surveys provide an ideal tool for studying fine- to broad-scale habitat associations for the surveyed taxa. Demersal fishes, including juvenile flatfishes, are often associated with habitat features such as sand waves, shells, drift algae and other biogenic structures (Auster et al., 1991; Norcross and Mueter, 1999; Stoner and Titgen, 2003). Survey methods that can include such microhabitat information along with quantification of a variety of taxa are valuable for analysis of habitat utilization. While algae and invertebrates are often captured in trawls as bycatch, observational or acoustic techniques are needed to quantify habitat features such as bedform and the structural context and scale of the bottom. In this study, densities of empty bivalve shells were accurately estimated with the camera sled and by the divers, but severely underestimated with beam trawls. With subsequent analyses of video coverage over various habitats, we have developed methods for quantifying habitat features that produce three types of data. We note: (1) general features of the sea bottom (e.g. flat, rippled, sand waves, and biogenic mounds); (2) score the density of biogenic features such as worm tubes, shell hash, and algal mats; and (3) count individual structures, such as shells, invertebrates, and algal clumps. Integration of the video recordings with navigational instrumentation supplies positional information that may then be incorporated into geographic information systems (GIS) for spatially explicit analyses on various spatial scales dependent upon the intensity of video coverage. Subsequent analyses can include predictive modelling of the spatial distribution of flatfishes and other taxa using habitat information not available in traditional collections of fishes with nets. The spatial analysis capabilities combined with the low cost and operational simplicity of the camera sled provides numerous advantages over ROVs and submersibles and makes it ideal for use by researchers with limited funds or technical support.

Acknowledgements

This study was supported by the Alaska Fisheries Science Center and a grant from the North Pacific Research Board (#R0301). N. Tagliavento built the prototype camera sled for this project and S. Webster helped to perfect the final design and fabrication. R. Titgen assisted with camera and video recording equipment. We are grateful to L. Barnett, P. Iseri, N. Tagliavento, and T. Tripp for help in the field.

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ATTACHMENT B

South Terminal Voronoi Cell Distribution and PCB Concentration			
Voronoi Cell	Volume (V)%	Concentration (Conc.)	V%*Conc.
10	3.201	5.9	0.19
11	5.182	14	0.73
12	2.379	7.9	0.19
13	2.998	20.4	0.61
14	2.958	7.7	0.23
15	3.564	7.6	0.27
16	4.127	6.7	0.28
17	0.529	4	0.02
18	2.953	2.2	0.06
19	3.799	1.5	0.06
20	3.192	8	0.26
21	0.109	1.2	0.00
22	1.343	20	0.27
23	5.197	4	0.21
24	0.112	1.4	0.00
25	1.891	2.4	0.05
26	0.149	0.5	0.00
27	3.615	8.6	0.31
28	0.505	0.91	0.00
29	3.746	6.3	0.24
30	1.651	5.3	0.09
31	2.419	17.05	0.41
32	1.765	6.4	0.11
33	1.593	6	0.10
34	2.935	3.6	0.11
35	0.020	2.7	0.00
36	1.669	5.5	0.09
37	1.683	9	0.15
38	1.716	0.26	0.00
39	1.857	0.8	0.01
40	1.684	1.1	0.02
41	1.487	1.6	0.02
42	0.002	4.9	0.00
43	1.741	0.26	0.00
44	1.651	3.22	0.05
45	1.424	10.6	0.15
46	0.671	0.23	0.00
47	1.238	0.23	0.00
48	1.551	7	0.11
49	1.487	18.6	0.28
50	1.579	0.6	0.01
51	1.654	15.3	0.25
52	1.230	14.2	0.17
53	0.271	16	0.04
54	0.007	5	0.00
55	0.032	0.29	0.00
56	1.637	6.6	0.11
57	1.639	8.19	0.13
58	1.415	9.9	0.14
59	0.032	0.53	0.00
60	1.626	3.1	0.05
61	1.471	11.7	0.17
62	1.405	5.6	0.08
63	1.456	2.4	0.03
64	1.251	9	0.11
65	1.503	15	0.23
		SUM of V%*Conc.	7.22
Concentration in mg/kg (1 mg/kg = 1ppm)		**Average Conc.**	7.22 mg/kg

Concentrations listed above for cells 10, 12-16, 18-22, 24-45, 47-52, & 55-65 are the results of chemical analysis by EPA Method SW846 8082/EPA 680 Modified.

Total PCB concentration for samples is estimated by summing 18 specific NOAA congeners and multiplying a harbor specific correction factor of 2.6. This harbor specific correction is based upon a statistical analysis conducted by the USEPA within New Bedford Harbor.

In the event of multiple samples per location, the highest concentration is shown in this table.

Samples with a "S" designation (i.e. S-af211), affecting cells 11, 17, 23, 46, 53, & 54, are samples from the USEPA's "Sediment Data Collected Through April 2003" PDF document downloaded from the New Bedford Harbor Superfund website. Concentrations are listed in Total PCB's in mg/kg as provided in that document.

Voronoi Cells 9 and 10 originate from the same sample, however, because they straddle two separate dredge footprints they have been split into two voronoi cells.

Federal Maneuvering Area Voronoi Cell Distribution and PCB Concentration			
Voronoi Cell	Volume (V)%	Concentration (Conc.)	V%*Conc.
1	7.331	8	0.
2	10.682	14	1.
3	49.059	2	0.
4	10.261	3	0.
5	3.008	13	0.
6	3.999	7	0.
7	8.653	14	1.
8	1.232	18	0.
9	5.774	5.9	0.
		SUM of V%*Conc.	5.
Concentration in mg/kg (1 mg/kg = 1ppm)		**Average Conc.**	5.82 mg/

Samples with a "S" designation (i.e. S-af211), affecting cells 1-8, are samples from the USEPA's "Sediment Data Collected Through April 2003" PDF document downloaded fror the New Bedford Harbor Superfund website. Concentrations are listed in Total PCB's in mg/kg as provided in that document.

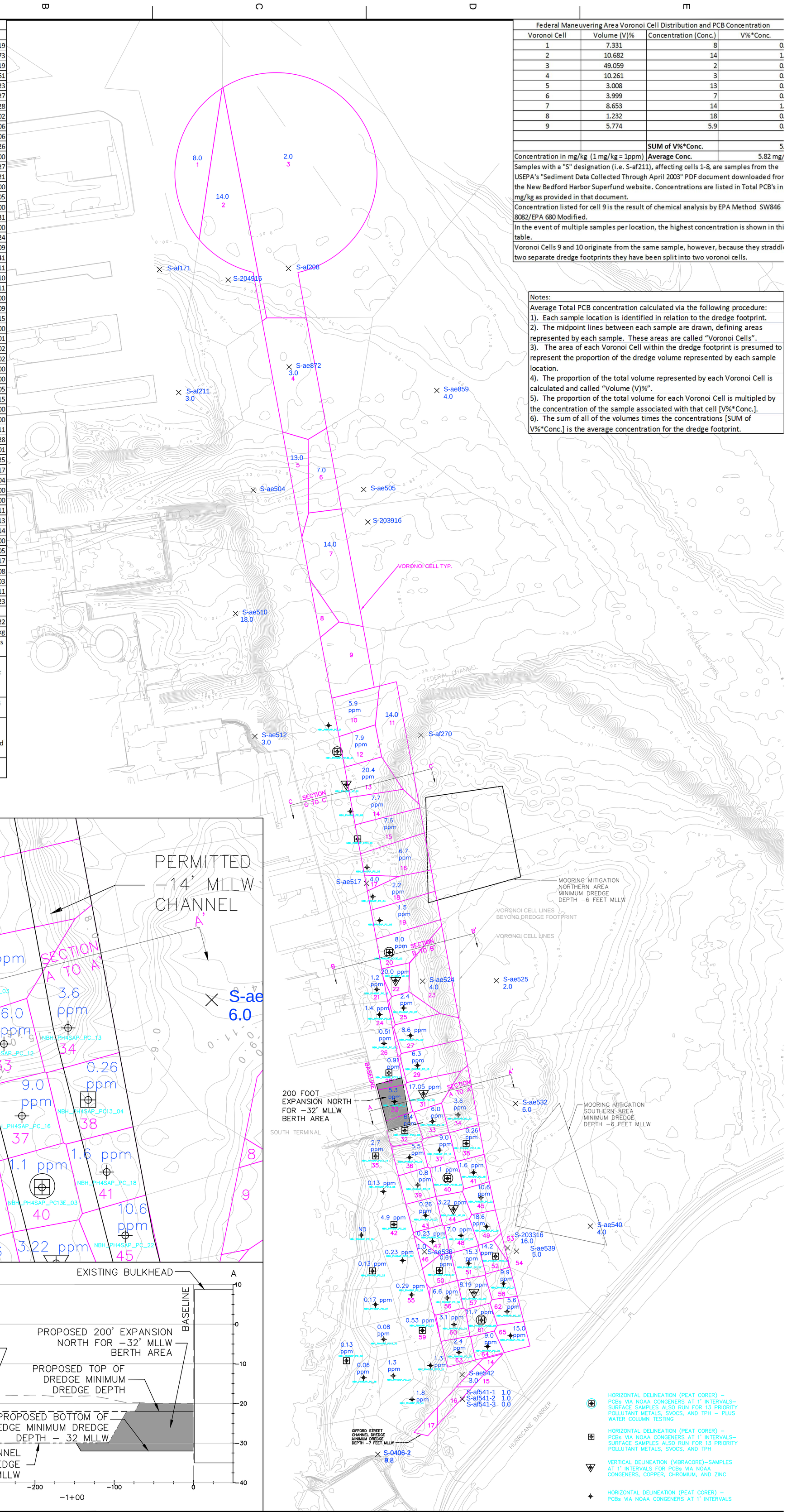
Concentration listed for cell 9 is the result of chemical analysis by EPA Method SW846 8082/EPA 680 Modified.

In the event of multiple samples per location, the highest concentration is shown in thi table.

Voronoi Cells 9 and 10 originate from the same sample, however, because they straddl two separate dredge footprints they have been split into two voronoi cells.

Notes:

Average Total PCB concentration calculated via the following procedure:
1). Each sample location is identified in relation to the dredge footprint.
2). The midpoint lines between each sample are drawn, defining areas represented by each sample. These areas are called "Voronoi Cells".
3). The area of each Voronoi Cell within the dredge footprint is presumed to represent the proportion of the dredge volume represented by each sample location.
4). The proportion of the total volume represented by each Voronoi Cell is calculated and called "Volume (V)%".
5). The proportion of the total volume for each Voronoi Cell is multipled by the concentration of the sample associated with that cell [V%*Conc.].
6). The sum of all of the volumes times the concentrations [SUM of V%*Conc.] is the average concentration for the dredge footprint.



DRAFT

PROJECT

NEW BEDFORD MARINE COMMERCE TERMINAL

OWNER

MASSACHUSETTS CLEAN ENERGY CENTER
55 SUMMER STREET, 9TH FLOOR
BOSTON, MASSACHUSETTS

NO.	DATE	DESCRIPTION	BY

PROJECT NO.	6690
CADD FILE	
DESIGNED BY	JER
DRAWN BY	JER
CHECKED BY	
DATE	06/5/2012
DRAWING SCALE	1"=200'
GRAPHIC SCALE	SCALE: 1"=200' 0 100 200 400
SHEET TITLE	SOUTH TERMINAL AND FEDERAL MANUEVERING AREA BATHYMETRY WITH EXPANDED BERTH
DRAWING NO.	V-5.4
	1 OF 1

APEX
ROCKVILLE, MD
SOUTH WINDSOR, CT - BOSTON, MA -
NEW BEDFORD, MA - HOLYOKE, MA
184 HIGH STREET, SUITE 502
BOSTON, MA 02210
58H CONNECTICUT AVENUE
SOUTH WINDSOR, CT

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ATTACHMENT C

Federal Maneuvering Area Voronoi Cell Distribution and PCB Concentration			
Voronoi Cell	Volume (V)%	Concentration (Conc.)	V%*Conc.
1	7.331	8	0.59
2	10.682	14	1.50
3	49.059	2	0.98
4	10.261	3	0.31
5	3.008	13	0.39
6	3.999	7	0.28
7	8.653	14	1.21
8	1.232	18	0.22
9	5.774	5.9	0.34
		SUM of V%*Conc.	5.82
Concentration in mg/kg (1 mg/kg = 1ppm)		**Average Conc.**	5.82 mg/kg

Samples with a "S" designation (i.e. S-af211), affecting cells 1-8, are samples from the USEPA's "Sediment Data Collected Through April 2003" PDF document downloaded from the New Bedford Harbor Superfund website. Concentrations are listed in Total PCB's in mg/kg as provided in that document.

Concentration listed for cell 9 is the result of chemical analysis by EPA Method SW846 8082/EPA 680 Modified.

In the event of multiple samples per location, the highest concentration is shown in this table.

Voronoi Cells 9 and 10 originate from the same sample, however, because they straddle two separate dredge footprints they have been split into two voronoi cells.

Notes:

Average Total PCB concentration calculated via the following procedure:

1). Each sample location is identified in relation to the dredge footprint.

2). The midpoint lines between each sample are drawn, defining areas represented by each sample. These areas are called "Voronoi Cells".

3). The area of each Voronoi Cell within the dredge footprint is presumed to represent the proportion of the dredge volume represented by each sample location.

4). The proportion of the total volume represented by each Voronoi Cell is calculated and called "Volume (V)%".

5). The proportion of the total volume for each Voronoi Cell is multipled by the concentration of the sample associated with that cell [V%*Conc.].

6). The sum of all of the volumes times the concentrations [SUM of V%*Conc.] is the average concentration for the dredge footprint.

South Terminal Voronoi Cell Distribution and PCB Concentration			
Voronoi Cell	Volume (V)%	Concentration (Conc.)	V%*Conc.
10	3.201	5.9	0.19
11	5.182	14	0.73
12	2.379	7.9	0.19
13	2.998	20.4	0.61
14	2.958	7.7	0.23
15	3.564	7.6	0.27
16	4.127	6.7	0.28
17	0.529	4	0.02
18	2.953	2.2	0.06
19	3.799	1.5	0.06
20	3.192	8	0.26
21	0.109	1.2	0.00
22	1.343	20	0.27
23	5.197	4	0.21
24	0.112	1.4	0.00
25	1.891	2.4	0.05
26	0.149	0.5	0.00
27	3.615	8.6	0.31
28	0.505	0.91	0.00
29	3.746	6.3	0.24
30	1.651	5.3	0.09
31	2.419	17.05	0.41
32	1.765	6.4	0.11
33	1.593	6	0.10
34	2.935	3.6	0.11
35	0.020	2.7	0.00
36	1.669	5.5	0.09
37	1.683	9	0.15
38	1.716	0.26	0.00
39	1.857	0.8	0.01
40	1.684	1.1	0.02
41	1.487	1.6	0.02
42	0.002	4.9	0.00
43	1.741	0.26	0.00
44	1.651	3.22	0.05
45	1.424	10.6	0.15
46	0.671	0.23	0.00
47	1.238	0.23	0.00
48	1.551	7	0.11
49	1.487	18.6	0.28
50	1.579	0.6	0.01
51	1.654	15.3	0.25
52	1.230	14.2	0.17
53	0.271	16	0.04
54	0.007	5	0.00
55	0.032	0.29	0.00
56	1.637	6.6	0.11
57	1.639	8.19	0.13
58	1.415	9.9	0.14
59	0.032	0.53	0.00
60	1.626	3.1	0.05
61	1.471	11.7	0.17
62	1.405	5.6	0.08
63	1.456	2.4	0.03
64	1.251	9	0.11
65	1.503	15	0.23
		SUM of V%*Conc.	7.22
Concentration in mg/kg (1 mg/kg = 1ppm)		**Average Conc.**	7.22 mg/kg

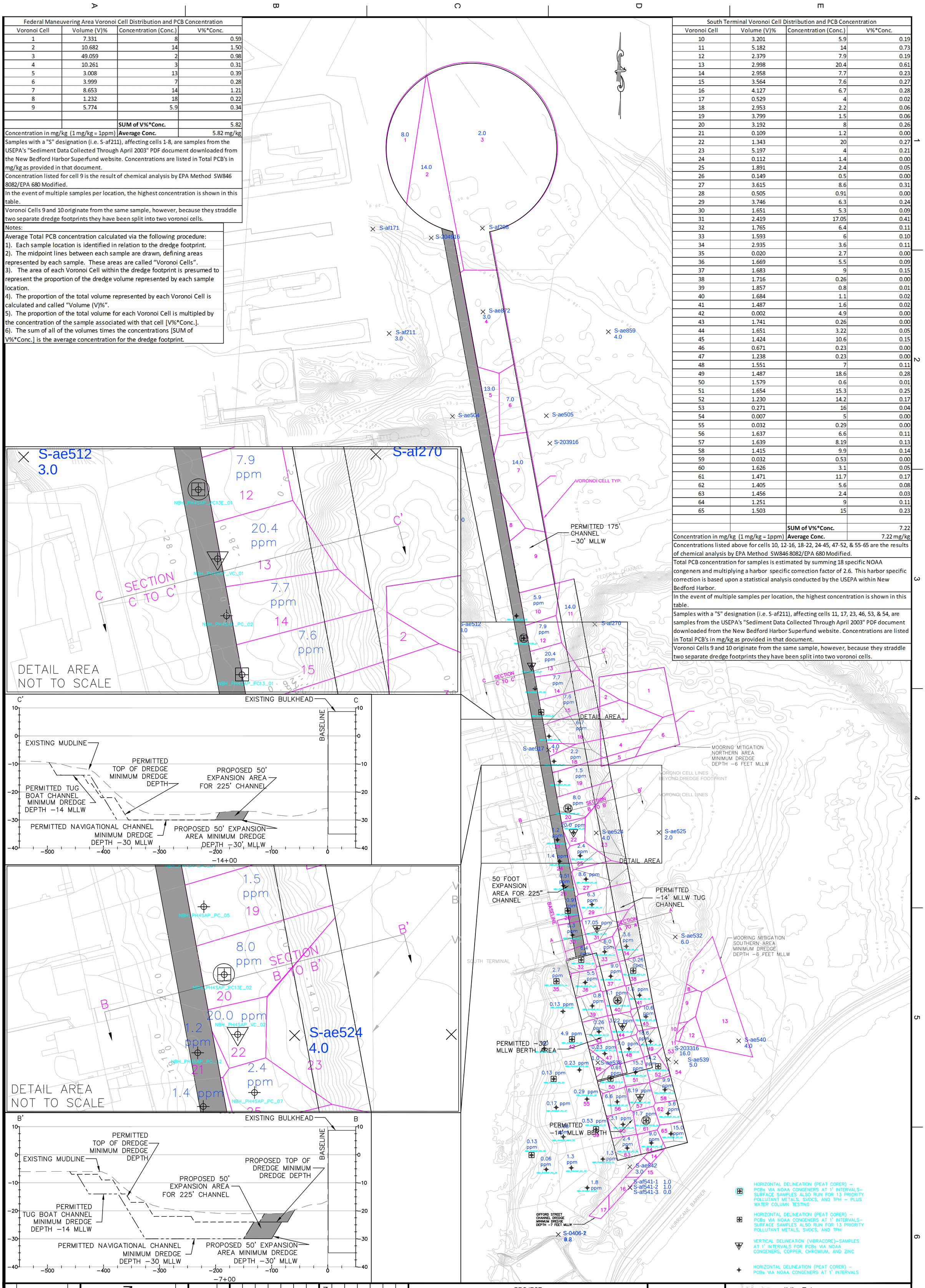
Concentrations listed above for cells 10, 12-16, 18-22, 24-45, 47-52, & 55-65 are the results of chemical analysis by EPA Method SW846 8082/EPA 680 Modified.

Total PCB concentration for samples is estimated by summing 18 specific NOAA congeners and multiplying a harbor specific correction factor of 2.6. This harbor specific correction is based upon a statistical analysis conducted by the USEPA within New Bedford Harbor.

In the event of multiple samples per location, the highest concentration is shown in this table.

Samples with a "S" designation (i.e. S-af211), affecting cells 11, 17, 23, 46, 53, & 54, are samples from the USEPA's "Sediment Data Collected Through April 2003" PDF document downloaded from the New Bedford Harbor Superfund website. Concentrations are listed in Total PCB's in mg/kg as provided in that document.

Voronoi Cells 9 and 10 originate from the same sample, however, because they straddle two separate dredge footprints they have been split into two voronoi cells.



DRAFT

APEX

ROCKVILLE, MD
SOUTH WINDSOR, CT - BOSTON, MA -
NEW BEDFORD, MA - HOLYOKE, MA

184 HIGH STREET, SUITE 502
BOSTON, MA 02210

58H CONNECTICUT AVENUE
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PROJECT

NEW BEDFORD
MARINE COMMERCE
TERMINAL

OWNER

MASSACHUSETTS CLEAN ENERGY CENTER
55 SUMMER STREET, 9TH FLOOR
BOSTON, MASSACHUSETTS

NO.	DATE	DESCRIPTION	BY

PROJECT NO.	6690
CADD FILE	
DESIGNED BY	JER
DRAWN BY	JER
CHECKED BY	
DATE	06/5/2012
DRAWING SCALE	1"=200'
GRAPHIC SCALE	SCALE: 1"=200' 0 100 200 400

SHEET TITLE

SOUTH TERMINAL
AND FEDERAL
MANUEVERING AREA
BATHYMETRY WITH
225 FT CHANNEL

DRAWING NO.

V-5.4

1 OF 1

ATTACHMENT D

BEALS + THOMAS

Civil Engineers ● Landscape Architects ● Land Surveyors ● Planners ● Wetland Scientists

Statement of Qualifications

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SERVICES

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Introduction

Project Types

Office/Corporate
Educational
Open Space & Conservation
Parks & Recreation
Golf Courses & Country Clubs
Healthcare
Residential
Industrial
Energy
Commercial/Retail
Municipal Planning, Facilities & Peer Reviews
Religious Facilities

Client Types

Architectural/Engineering Firms
Attorneys
Financial Institutions
Commercial/Retail Businesses
Manufacturers
Conservation/Non-profit Organizations
Government Agencies
Real Estate Developers
Contractors
Utility Companies
Private Entities

Founded in 1984, Beals and Thomas, Inc. is a multidisciplinary consulting firm providing professional services in support of the development and conservation of land and water resources throughout New England. We offer creative and solution-oriented land planning and design services that are balanced with an environmental ethic. Our approach ensures comprehensive management and attention to detail by combining the experience of civil engineers, landscape architects, environmental specialists, planners and land surveyors. This is the foundation of our success and reputation.

Beals and Thomas provides a professional environment that achieves successful results for our clients, shareholders and employees alike. Our reputation for dependable, thorough service cultivates solid business relationships and enhances our broad range of experience with public and private sectors.

Integrated design teams provide the skills and management necessary to address your needs in a comprehensive manner. Our multidisciplinary design group structure affords team members exposure to the abilities of each discipline and the opportunity to provide complementary skills. This cooperative approach not only builds upon the proficiency of our professional staff but also achieves responsive and cost-effective solutions for our clients.

Our Statement of Qualifications provides an overview of services, project experience, and the capabilities of our professional staff. We encourage you to contact us for more in-depth information about Beals and Thomas and how we can help you achieve your project goals.

Civil Engineering

Analysis & Capacity Studies

Soil Evaluations
Utility Infrastructure
Water Systems
Subsurface Sewage Disposal
Sewer Systems & Pump Stations
Hydrology & Drainage Systems
Stormwater Management Design
Grading Studies & Earthwork Analysis
Site Distance Analysis
Roadway & Intersection Capacity
Hydrogeologic Modeling

Engineering Design Development

Stormwater Management Planning
Low Impact Development Techniques
Roadway & Pavement Design
Intersection Design
Retaining Wall Design
Infiltrative Drainage Systems
Sewage Pump Stations

Representative Products

Bedrock & Soils Maps
Utility Plans & Profiles
Roadway & Intersection Plans
Grading & Drainage Plans
Bid & Construction Documents
Technical Specifications
Construction Observation & Administration

Thoughtful site design and cost-effective civil engineering create the framework for any successful development. Our engineers apply effective and practical design solutions at the onset, ensuring that engineering solutions are integrated with all aspects of the project. We provide creative problem solving, conceptual and final design, computer-aided design and drafting, calculations, project management services and plan processing through agency approvals.

We practice the traditional aspects of civil engineering including grading, drainage, utility design, site layout, water supply and distribution system design, and wastewater collection and disposal system design. During the preliminary phase of a project, our engineers analyze various alternative plans to determine feasibility and cost efficiency. State-of-the-art computer technology is used to facilitate timeliness in the completion of all our projects.

Before & after conditions of the MBTA Green Line viaduct at Archstone North Point - Cambridge, MA

Environmental

Data Collection & Analysis

Wetland Mapping
ASTM Environmental Site Assessments
Water Quality Sampling Program
Groundwater Flow Models
Massachusetts Contingency Plan
Mobile Source Air Quality Analysis
Botanical/Wildlife Assessments
Natural Resource Inventories
Greenhouse Gas Modeling

Design

Wetland Restoration & Replication
Stormwater Best Management Systems
Stormwater Pollution Prevention Plans
Remediation Measures for Site Contamination
Aquifer Protection Criteria
Land & Water Management Plans
Solid Waste Landfills Remediation
Erosion Control & Bioengineering of Slopes
Soil Conservation
Conservation Restriction Planning

Local, State, & Federal Permitting

Subsurface Sewage Disposal Permits
Wetlands Permits
Water Quality Certifications
Groundwater & Surface Water Discharge Permits
Waterways Licenses
Environmental Impact Reports
NPDES Plans
Army Corps of Engineers Permits
EPA Permits & Certifications
Water Management Act Permits

Increasingly stringent environmental legislation requires integrated professional services that balance client goals with environmental considerations. Our staff has extensive knowledge of environmental regulations, and maintains mutually cooperative working relationships with regulatory agency professionals throughout our practice areas.

Our environmental services staff provides detailed site analysis and system designs to address air, soil, and water quality issues. Our record of successfully permitted and constructed projects reflects the dedication and versatility of our staff. In recognition of our innovative approach and environmental sensitivity during the land planning and design processes, Beals and Thomas was awarded the Small Business Friend of the Environment Award by the Environmental Federation of New England and The Nicholas Humber Environmental-Energy Award for Outstanding Collaboration from the Environmental Business Council of New England.

Salt marsh design at River's End Park, New Bedford, MA

Landscape Architecture

Site Analysis & Project Programming

Land Use Regulation Analysis
Site Analysis
Viewshed Studies
Programming Evaluation & Testing
Natural Resource Inventory & Analysis
Vegetation Inventories
Solar & Shadow Analysis

Design Development

Master Planning
ADA Compliance
Feasibility Studies
Circulation Design
Site Improvement Plans
Illustrative Presentation Plans
Materials Selection & Layout
Screening & Buffer Design
Site Grading Design
Site Lighting Design
Planting Design
Site Details

The visual quality of a project can evoke strong reactions from potential investors, tenants, customers and regulatory officials. For a project to be successful, it must meet economic goals and achieve the functional and aesthetic goals of the client. Our landscape architects are rational and creative as they balance aesthetics, design efficiency, and construction costs to produce projects that are economical, marketable and visually pleasing.

With an advanced understanding of site design and an approach that encourages collaboration with civil engineers, surveyors, and environmental professionals, we design projects to be compatible with the existing topography, landscape, and regulatory environment. We incorporate critical details to advance project team goals and ensure a cohesive design. The finished product demonstrates our commitment to the landscape architectural process and assures our clients' satisfaction and success.

Cronin's Landing Riverwalk

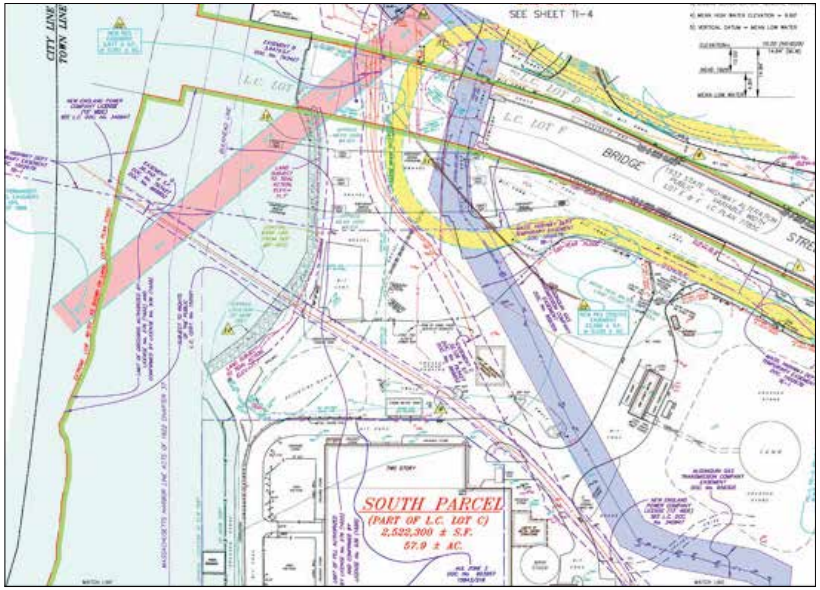
Goodwill Park - Holliston, MA

Land Surveying

Architectural Detail Surveys
Design Base Plans
Utility Surveys
Lot Staking
Plot Plans
Building Permit Plans
Settlement Surveys
Specialty Surveys
As-built Surveys
Aerial & Topographic Surveys
Hydrographic Surveys
Land Records Compilation & Storage
Boundary Surveys
Land Court Surveys
Title Insurance Surveys
Zoning Studies
License Studies
Metes & Bounds Descriptions
Easement Plans & Surveys
MCP Activity & Use Limitation Surveys
Right-of-Way Surveys
Construction Layout
GIS Services
GPS Surveys
Baseline Control Surveys

Accurate collection and presentation of survey data is critical to a project's development and success. We understand that efficient data gathering, coupled with effective communication, is crucial when working with clients, design professionals, and permitting authorities to complete project goals on time and within budget.

Experienced use of technologically advanced tools enables our survey staff to handle a wide variety of assignments. Projects of varying size and scope are completed in less time and with increased precision because of our proficiency with state-of-the-art methods. Information is presented in clear and understandable formats through the use of color technology and unique data displays.



Color-coded survey plan for better interpretation of data

Planning

Economic & Industrial Development
Employment Generation
Revitalization of Declining Commercial Areas
Tax Base Analysis
Zone Changes

Community Planning
Master Planning
Build-out Analysis
Consensus Building
Public Participation
Open Space & Recreation Plan
Visioning & Goal Setting
Land Conservation Strategies

Community Impact Analysis
Municipal Services/School Impacts
Fiscal Analysis
Project Feasibility Analysis
Housing Inventories & Needs Assessment

Land Use Regulations & Permitting
Permit/Regulatory Analysis
Regulatory Revisions
Plan Submission Reviews
Local Zoning, Subdivision, General Bylaws
State MEPA, Chapter 91, Housing, Wetlands
Federal NEPA, Historic , Army Corps Water Quality Certification

Managed community growth and economic revitalization, in unison with the preservation of open space and community character, is the mission of the planning staff. We offer experience and a broad viewpoint when working within a community to find the answers to land use, economic development, housing, and growth management issues.

We provide innovative strategies, problem solving, and flexibility during the planning and permitting phases of a project to achieve project goals in concert with the requirements of governing authorities. We act as a liaison between our clients, communities and regulatory officials to better facilitate the development and permitting processes, and maximize the social, physical, and economic benefits of a community's natural and built environments.

Sustainable Design

Sustainable Site Design
Low Impact Development
Water Efficient Design
Renewable Energy Design & Modeling

Sustainable design is a comprehensive approach to building construction and renovation, while minimizing the impact on public health and the environment. Sustainable developments aim to reduce environmental impacts not only during construction, but also during renovation and demolition. Ideally, green building serves as a means for providing long-term, economically sustainable solutions that preserve our natural resources and enhance our quality of life.

Beals and Thomas continues its role as a leader in environmentally responsible design by taking a lead in green design. We are committed to finding creative strategies that improve our environment and protect public health efficiently and cost-effectively.

Alternatives, Inc. (LEED Gold Certified) - Whitinsville, MA

The MITRE Center (LEED Silver Certified) - Bedford, MA

Leadership in Energy and Environmental Design (LEED)

The LEED Green Building Rating System is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. Based on well-founded scientific standards, LEED emphasizes state-of-the-art strategies for sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality.

LEED Accredited Professionals are experienced building industry practitioners who have demonstrated their knowledge and understanding of green building practices and principles, and familiarity with LEED requirements, resources, and processes.

Representative LEED Projects:

The Home for Little Wanderers Longview Farm, Walpole, MA
Fay School, Southborough, MA
Cambridge City Hall Annex, Cambridge, MA
Doyle Conservation Center, Leominster, MA
Starwood *element* Hotel, Lexington, MA
ISO New England, Holyoke, MA
Whitin Mill Redevelopment, Whitinsville, MA
The MITRE Center, Bedford, MA

project**portfolio**

Concord Meadows Corporate Center

Weston Corporate Center

Wakefield Office Park

Cisco Systems

REPRESENTATIVE PROJECTS

Weston Corporate Center
Weston, MA

Concord Meadows Corporate Center
Concord, MA

i-Park
Waltham, MA

Cisco Systems, Inc.
Boxborough, MA

Tyngsborough Business Park
Tyngsborough, MA

National Grid Headquarters
Westborough, MA

EMC Corporation
Hopkinton/Southborough/Westborough, MA

Worcester Telegram & Gazette
Millbury, MA

Lantheus Medical Imaging
Billerica, MA

Westborough Office Park
Westborough, MA

Wakefield Office Park
Wakefield, MA

The MITRE Corporation
Bedford, MA

Worcester Corporate Center
Worcester/West Boylston, MA

EMC Corporation

The MITRE Corporation

American Red Cross and Emuge at Worcester Corporate Center

Office Buildings/Parks

Facilities/Maintenance Building and Primary School at the Fay School

Carmelite Sisters Monastery

Revere Police Headquarters

Kerem Shalom Synagogue

REPRESENTATIVE PROJECTS

Fay School
Southborough, MA

Society of St. John the Evangelist Monastery
& Guest House
Cambridge, MA

Grace Chapel
Wilmington, MA

Abby Kelley Foster Charter Public High School
Worcester, MA

The Home for Little Wanderers Longview Farm
Walpole, MA

Doyle Conservation Center
Leominster, MA

Kerem Shalom Synagogue
Concord, MA

Carmelite Sisters Monastery
Danvers, MA

Quinsigamond Community College
Worcester, MA

Old Quincy House at Harvard University
Cambridge, MA

Veteran's Training & Rehabilitation Center
Gardner, MA

School Entrance at The Home for Little Wanderers Longview Farm

Abby Kelley Foster Charter Public High School

Institutional

Doyle Conservation Center

Coastal Bank Stabilization, Cape Cod

Boatslip Remediation & Mitigation in New Bedford Harbor

REPRESENTATIVE PROJECTS

Coastal Bank Stabilization
Wellfleet, MA

Doyle Conservation Center
Leominster, MA

World's End Reservation
Hingham, MA

MGP Site Boatslip Remediation & Mitigation
New Bedford, MA

Coolidge Point
Manchester-by-the-Sea, MA

River Run
Wareham/Plymouth, MA

Hillview Wetland Crossing
Winchendon, MA

DCR Land Planning Study
Dighton, MA

The Trustees of Reservations
Various Massachusetts Locations

Gooseneck Cove Estuary & Salt Marsh Restoration
Newport, RI

Merrimack River Bank Stabilization
Haverhill, MA

Gooseneck Cove Estuary

World's End Reservation Damde Meadows Restoration

Conservation

Goodwill Park

Holliston Soccer Fields

University Park

Massachusetts International Academy Sports Complex

REPRESENTATIVE PROJECTS

University Park
Worcester, MA

Goodwill Park
Holliston, MA

Beech Tree Park at Village Hill Northampton
Northampton, MA

Elm Park
Worcester, MA

Houghton's Pond Ball Fields
Milton, MA

Fay School Athletic Fields
Southborough, MA

Massachusetts International Academy Sports Complex
Marlborough, MA

Holliston Soccer Fields
Holliston, MA

Lovell's Grove & King's Cove Park
Weymouth/Quincy, MA

Brae Burn Country Club
Newton, MA

DCR Lower Falls Trail Segment
Newton/Wellesley, MA

Needham Master Trails Plan
Needham, MA

Franklin Country Club
Franklin, MA

Fay School Athletic Fields

Beech Tree Park at Village Hill Northampton

Elm Park

Recreation

Shovel Shop Apartments

Jefferson at Admiral's Hill

Scouting Way Apartments

Residence Building at the The Home for Little Wanderers Longview Farm

BEALS + THOMAS

REPRESENTATIVE PROJECTS

North Point
Cambridge, MA

Shovel Shop Apartments
Easton, MA

Archstone NorthPoint
Cambridge, MA

Arlington 360
Arlington, MA

Village Hill Northampton
Northampton, MA

Winterberry Hollow
Holden, MA

The Home for Little Wanderers Longview Farm
Walpole, MA

Scouting Way Apartments
Cambridge, MA

Hearth Ridge Manor
Hopkinton, MA

Mount Hope Farm Estates
North Attleborough, MA

Eaton Place
Franklin, MA

Maple Springs
Wareham, MA

Legacy Farms
Hopkinton, MA

Jefferson at Admiral's Hill
Chelsea, MA

Tihonet Pond
Wareham, MA

NorthPoint

Village Hill Northampton

Eaton Place

Residential

REPRESENTATIVE PROJECTS

Emerson Hospital
Concord, MA

Lawrence General Hospital
Lawrence, MA

Merrimack Valley Hospice
Haverhill, MA

Brooksby Village
Peabody, MA

Taunton State Hospital
Taunton, MA

University of Massachusetts Medical
Worcester Foundation Campus
Shrewsbury, MA

Cambridge Health Alliance/Malden Medical Center
Malden, MA

American Red Cross Regional Headquarters
West Boylston, MA

Lantheus Medical Imaging
Billerica, MA

Center for Specialty Care, Bone and Joint Center
Concord, MA

Garcia Dental
Raynham, MA

Brighton Marine Healthcare Center
Brighton, MA

Emerson Hospital

Lawrence General Hospital

Emerson Hospital Life Flight Helipad

American Red Cross of Central Massachusetts

Healthcare

BEALS + THOMAS

REPRESENTATIVE PROJECTS

A. Duie Pyle Distribution Center
Northborough, MA

Romanow Container
Westwood, MA

FLEXcon
Spencer, MA

CSX Terminal Redevelopment
Westborough, MA

Pound Hill Industrial Park
North Smithsfield, RI

Myles Standish Industrial Park
Taunton, MA

Bird Machine Company
Walpole, MA

Avon Industrial Park
Avon, MA

Cedar Hill Industrial Park
Marlborough, MA

ISO New England
Holyoke, MA

A. Duie Pyle

TRANSFLO Westborough Terminal

ISO New England

FLEXcon

Industrial

REPRESENTATIVE PROJECTS

Rosebrook Solar Energy Array
Wareham, MA

Charlotte Furnace Solar Array
Wareham, MA

Russell Biomass Power Facility
Russell, MA

Pilgrim Nuclear Power Station
Plymouth , MA

Fore River Power Station
Weymouth, MA

Mystic Station
Everett, MA

Mystic Generating Station

Charlotte Furnace Road Solar Array

Fore River Power Station

Pilgrim Nuclear Power Station

Energy

BEALS + THOMAS

REPRESENTATIVE PROJECTS

aloft and element Hotels
Lexington, MA

Raynham Woods Commerce Center
Raynham, MA

Long Automotive Dealership
Southborough, MA

Silko Honda
Raynham, MA

Texas Roadhouse Restaurant
Warwick , RI

Long Automotive

Raynham Woods Commerce Center

element and aloft Hotels

Silko Honda

Commercial

Leadership

Gerry Preble, PE, LSP
President

Richard P. Kosian, PE, LEED AP
Executive Vice President

John E. Thomas, PWS
Vice President

Mary-Ellen Odone
Treasurer

John E. Bensley, PE
Principal

Robert J. Buckley, PLS
Principal

Kenneth Conte, PLS
Principal

Daniel M. Feeney, PE, LEED AP
Principal

Eric J. Las, PE, LEED AP
Principal

Robert E. Weidknecht, RLA, LEED AP
Senior Associate

David J. LaPointe, RLA, LEED AP
Associate

Stacy H. Minihane, PWS
Associate

Corporate Registrations and Certifications

Professional Engineers
Massachusetts, Connecticut, Maine, New Hampshire, Rhode Island, Vermont

Professional Land Surveyors
Massachusetts, Connecticut, Rhode Island

Registered Landscape Architects
Massachusetts, Connecticut, Maine, New Hampshire, Rhode Island

Professional Wetland Scientists
National

Licensed Site Professionals
Massachusetts

U.S. Green Business Council LEED Accredited Professionals
National

American Institute of Certified Planners
National

Approved Title V System Inspectors
Massachusetts

Approved Soil Evaluators
Massachusetts

BEALS + THOMAS

CORPORATE OFFICE
Reservoir Corporate Center
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Southborough, MA 01772
T: 508.366.0560 F: 508.366.4391
www.btiweb.com

REGIONAL OFFICE
32 Court Street
Plymouth, MA 02360
T: 508.746.3288 F: 508.746.6407

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BEALS AND THOMAS, INC.
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Plymouth, Massachusetts
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T 508.746.3288
F 508.746.6407
mail@btiweb.com I www.btiweb.com
Corporate Office: Southborough, MA

March 19, 2013

Mr. Chet Myers
Apex Companies, LLC
125 Broad Street, 5th Floor
Boston, MA 02110

Via: email: cmyers@apexcos.com

Reference: Qualifications
Rivers End
New Bedford, Massachusetts
Project No. M5068.31

Dear Chet:

As requested, we are pleased to provide information relating to our relevant experience for the Rivers End salt marsh project. Beals and Thomas, Inc. (B+T) has significant experience with wetland and coastal resource creation/restoration, invasive species control, and construction management. We would be pleased to provide additional information/detail beyond that addressed herein as would be helpful.

Firm Profile
The B+T team has a significant depth of experience with site survey, riparian zone restoration, wetland creation, upland rehabilitation, landscape design, invasive species management, public usage/access network design and signage, and the myriad of environmental permitting associated with coastal and inland restoration and rehabilitation projects.

For over 27 years, Beals and Thomas, Inc. (B+T) has been providing professional services that support the development and conservation of land and water resources throughout New England. We are committed to preserving the integrity of the New England landscape through sound environmental design, and have established a corporate identity based on a balanced perspective with the planning, development, and conservation of land and water resources.

We specialize in land surveying, civil engineering, environmental services, landscape architecture, planning, permitting and wetlands consulting. The combined perspective of our multidisciplinary in-house team provides the leadership and management necessary to address client and project needs in a comprehensive and responsive manner. We dedicate the necessary time and staff resources to meet project deadlines and ensure that our clients are uniquely prepared to respond to a range of issues with timely and cost-effective solutions. Our experience and ability to manage large, complex projects includes a sensitivity to which land development goals and objectives are balanced with environmental and regulatory considerations.

B+T has completed a range of creation, restoration, and enhancement design, permitting, evaluation/monitoring, and construction administration services for various projects involving coastal estuaries and salt marshes, freshwater wetlands, rivers, streams and ponds. We also have demonstrated experience in planning, designing and implementing public spaces, including facilitating access and enhancing educational signage. Our corporate ethic has resulted in the establishment of solid relationships with various non-profit organizations, and we have provided services (including pro-bono work) for various environmental and recreation based groups, including The Trustees of Reservations, the Massachusetts Corporate Wetland Restoration Partnership, MassAudubon, Hale Reservation, Charles River Watershed Association, Mission Impossible, Home for Little Wanderers, and Hopkinton Community Playground, among others. Additionally, B+T recently received the Environmental Business Council's Nicholas Humber Environmental – Energy Award for Outstanding Collaboration and is a past recipient of the Environmental Federation of New England's Environmental Friend of New England Award.

Project Team

Please also refer to the enclosed resumes. Additionally, please note that, between myself and Eric, we have worked on nearly all of the projects described in the attached representative project sheets.

Eric Las, PE, LEED AP, Principal. Mr. Las is experienced in coastal and inland wetland, pond and stream ecology, wetland creation, restoration and enhancement, hydrologic and hydraulic analysis, stormwater management, earthwork analysis, value engineering, cost estimating, and construction administration. Mr. Las currently serves on the Board of Directors and as Treasurer for the Massachusetts Congress of Lake & Pond Associations.

Stacy Minihane, PWS, Associate. Ms. Minihane has broad experience in wetland science, resource area delineation, environmental research and local, state, and federal permitting processes. Her responsibilities include the execution and oversight of wetland and coastal resource area delineations, wildlife habitat evaluations and natural resources inventories, performance of field work to evaluate and monitor restoration/creation sites (pre-construction, during construction, and post-construction), and preparation and oversight of complex environmental and wetland-related reports and permitting documents.

Please do not hesitate to contact me should you require anything further.

Very truly yours,

BEALS AND THOMAS, INC.

Stacy H. Minihane

Stacy H. Minihane, PWS
Associate

Enclosures: Resumes
Representative Project Sheets
Statement of Qualifications (under separate cover)

cc: Mr. Kenneth Fields, Apex Companies, LLC (via email: KFields@apexcos.com)

SHM/M506831LT001

Mr. Las manages the Planning and Environmental Services department at Beals and Thomas, Inc. He is responsible for project direction and management, civil and environmental design, and permitting for industrial, commercial, residential, conservation, and restoration projects. Mr. Las is experienced in pond and stream ecology, lake and pond management, wetland creation, restoration and enhancement, dredging design, hydrologic analysis, hydraulic system design, earthwork analysis, value engineering, cost estimating and construction administration.

Mr. Las's experience with local, state, and federal permitting includes preparation of application packages for Notice of Intents, Environmental Notification Forms, 401 Water Quality Certifications, Ch. 91 Permits and Licenses, Conservation and Management Permits, and Army Corps PGP's and Individual Permits among others.

Mr. Las currently serves on the Board of Directors for the Massachusetts Congress of Lake & Pond Associations (MACOLAP), as well as Treasurer for the organization.

Relevant Experience

Fay School FEMA Flood Study, Southborough, MA

Project Manager and Professional responsible for challenging FEMA on published FIRM map flood elevation. Obtained historic flood study from FEMA and analyzed the model for several sub-basins within the Sudbury Reservoir waterway using HEC-RAS and HEC-2 modeling software. Identified errors with the official FEMA flood study and associated FIRM map. Prepared corrected flood study models and submitted to FEMA with request for map revision. Successfully obtained Letter of Map Revision from FEMA that reduced flood elevations within subject property by nearly two (2) feet.

Charles River Wetlands Restoration, Millis, MA

Project Director and Professional Engineer responsible for wetland and bank restoration design plans as part of an enforcement order at a residential property located on the Charles River. The project involved restoration of over one acre of scrub shrub wetland that had been historically filled without necessary permits. The project also involved the stabilization and restoration of a portion of the bank along the Charles River that had also been developed. Involved frequent consultation with the DEP during the design process to ensure that the design plans included sufficient wetland area and flood storage capacity.

Pilgrim Station, Plymouth, MA

Project Director and Professional Engineer responsible for engineering and obtaining permit approvals for maintenance dredging of 65,000 c.y. of sediment from an existing cooling-water intake channel. Coordinated and prepared dredging volumes estimates, regulatory analysis, sediment sampling and analysis, dredging design plans, permit applications, technical specifications and bid documents. Completed permitting with the ACOE, MEPA, DEP , CZM, and the Plymouth Conservation Commission. Provided dredging and environmental oversight throughout the dredging process.

Education

B.S., Civil Engineering, Worcester Polytechnic Institute, 2001

Professional Registrations

Professional Engineer – MA

LEED Accredited Professional

Certified Soil Evaluator - MA

Professional Associations

Charles River Watershed Association

Conservation Law Foundation

Massachusetts Congress of Lake & Pond Associations (MACOLAP)

Years of Experience

Total Experience: 12.5
With Beals and Thomas, Inc.: 12

World's End Reservation, Hingham, MA
Project Director overseeing permitting and design support relating to the two-phase removal of two existing box culverts, dredging of 2,500 cubic yards to create open channels, and construction of a new vehicular-rated pedestrian bridge in Hingham Harbor and Damde Meadows Salt Marsh. Extensive coordination for authorization was required with multiple agencies, including ACOE, NOAA, DEP, NHESP, MHC, DMF, CZM, MEPA, and the Hingham Conservation Commission.

Carding Mill Pond Dredging Feasibility, Sudbury, MA
Project Director and Profesional Engineer responsible for preparation of a feasibility study for the dredging of the 41-acre Carding Mill Pond to improve water quality, restore fisheries habitat and control nuisance aquatic vegetation. Performed a wildlife habitat evaluation, bathymetric survey, and sediment depth survey. Prepared schematic design plans for hydraulic and conventional dry dredging options. Preparation of cost estimates and coordination of pre-application meetings with ACOE, DEP, DFW, and the Sudbury Conservation Commission are on-going.

Wight Pond, Dedham, MA
Project Manager responsible for performing qualitative aquatic survey of 3.8-acre private pond. Survey included bathymetry, substrate analysis, water quality sampling, fish inventory, and vegetation mapping. Prepared pond management report with recommendations for improving pond habitat to support a warm-water recreational fishery and control nuisance aquatic vegetation. Coordinated preparation of Notice of Intent Application for pond hydroraking and obtained Order of Conditions from Conservation Commission.

Concord Country Club, Concord, MA
Project Manager responsible for preparation of technical specifications and bid documents for dredging of over 2,000 c.y. of sediment from two golf course ponds. Coordinated bidding process for client and provided on-site dredging oversight and guidance throughout project. Performed environmental sampling and evaluated laboratory results from on-site surface and groundwater sources pre- and post-dredging.

Coolidge Point Stream Restoration, Manchester-by-the-Sea, MA
Project Director and Professional Engineer responsible for coastal and wetland resource area delineation, land surveying, engineering design, and permitting services for restoration of a portion of the tidal creek connecting Clark Pond to Kettle Cove at Coolidge Point. The project involves the reduction of a hydraulic restriction at a pedestrian crossing over the tidal creek. The project is intended to increase the capacity for tidal flow into Clark Pond, restore Land Subject to Tidal Action, and reduce flooding of upland areas bordering Clark Pond during significant rainfall events.

Private Pond, Woodstock, VT
Project Manager responsible for performing a qualitative aquatic survey of a 2.8-acre private pond. Survey included bathymetry, substrate analysis, water quality sampling, fish inventory, and aquatic vegetation mapping. Prepared a pond management report with recommendations for improving pond habitat to support a cold-water trout fishery and control nuisance aquatic vegetation. Obtained regulatory approvals for maintenance dredging and prepared dredging cost estimate for client consideration.

Private Residence, Hopkinton, MA
Project Engineer responsible for design of two synthetic-lined ponds with groundwater and re-circulation pumping systems. Coordinated bedrock well drilling for pond supply and irrigation. Prepared design plans, bid documents, and technical specifications for bidding and construction. Provided full-time on-site construction oversight and guidance, and coordination of general contractors and subcontractors. Provides on-going consulting services to property manager and client for maintenance and management of ponds as a cold-water trout fishery.

Publications and Presentations

Las, E. "Dredging Feasibility Studies" *Massachusetts Congress of Lake and Pond Associations, Water Wisdom Newsletter*. Winter 2012 (January 2012): 1-3. Print.

Las, E. "Dredging Permit Process" *Massachusetts Congress of Lake and Pond Associations, Water Wisdom Newsletter*. Summer 2010 (May 2010): 7. Print.

Workshop presentation at the Society of Wetland Scientists New England Chapter Conference. *Massachusetts Wetland Banking Pilot*. Worcester, MA. (November 2006).

Las, E., Minihane. S., & Miley. D., "A Pilot Wetlands Mitigation Bank in the Taunton River Watershed" *Association of Massachusetts Wetlands Scientists Newsletter*. Vol No 59 (October 2006): 8-9. Print.

Ms. Minihane has extensive experience in wetland science, resource area delineation, environmental research and local, state, and federal permitting processes. Her responsibilities include the execution and oversight of wetland delineations, wildlife habitat evaluations and natural resources inventories, and preparation and oversight of complex environmental and wetland-related reports and permitting documents. She also provides project peer review services for various Conservation Commissions in Massachusetts. Internally, Ms. Minihane educates colleagues on changes in environmental regulations through her writings and in-house seminars.

Relevant Experience

World's End Reservation, Hingham, MA

Project Manager responsible for permitting associated with the removal of two culverts, dredging to create open channels, and construction of a bridge in Hingham Harbor and Damde Meadows Salt Marsh. Phase One of the project was undertaken by obtaining emergency approvals. Post-construction permitting for Phase One and permitting for Phase Two has been completed and included MEPA Environmental Notification Form, Chapter 91 License, 401 Water Quality Certification, Category 2 General Permit, Notice of Intent and coordination with the Natural Heritage & Endangered Species Program and Massachusetts Historical Commission.

Boat Slip Remediation and Mitigation, New Bedford, MA

Project Manager responsible for 401 Water Quality Certification, Chapter 91 License, Notice of Intent, Notice of Project Change, and Army Corps of Engineers Category 2 Applications associated with the remediation of a 26,000 sf contaminated boat slip in New Bedford Harbor. Coordinated extensively with regulatory agencies. Oversaw mitigation alternatives analysis. Currently designing and preparing required permits for 15,000 square foot salt march creation area as mitigation.

Shoreline Stabilization, Quincy, MA

Performed vegetative monitoring, prepared annual reports documenting the status of the stabilization area, and assisted with permitting including Chapter 91 and Certificates of Compliance.

Hartwell Forest, Bedford, MA

Assisted with the evaluation of potential boardwalk locations to provide access across wetlands. Delineated associated wetlands.

Old Town Hill, Salt Marsh Restoration, Newbury, MA

Assisted with a Request for Determination of Applicability and attended associated hearings for the restoration of tidal flows and disturbed areas, as well as prevention of future degradation of the resource area. The project was undertaken in partnership with The Trustees of Reservations, the MA Wetland Restoration Program, the National Marine Fisheries Service and the Gulf of Maine Council.

Wetlands Banking Pilot, Hanson, MA

Performed wetland delineation in accordance with state and federal requirements. Assisted with the design of wetland restoration and creation areas, as well as a riparian corridor. The design included 9.3 acres of wetland creation in disturbed uplands and 16.2 acreas of wetland enhancement, including an Atlantic White Cedar community, in abandoned cranberry bogs. Participated in interagency meetings with MA DEP, Army Corps of Engineers, MA DFW, and MA EOEEA.

Education

B.A., Biology and Environmental Studies, Bowdoin College, 2003

Professional Registrations

Professional Wetland Scientist

Professional Associations

Association of Massachusetts Wetland Scientists

Society of Wetland Scientists

Years of Experience

Total Experience: 9
With Beals and Thomas, Inc.: 9

Hale Reservation, Westwood, MA
Performed a natural resources inventory of the 1,200-acre site, including mapping of plant communities, vernal pool assessments, water quality, wildlife observations and management recommendations. The inventory also included an evaluation of the existing trail system and associated recommendations.

Wight Pond, Dedham, MA
Conducted site reconnaissance to assist with the identification and delineation of bank, bordering vegetated wetland, and intermittent stream areas. Prepared an associated Abbreviated Notice of Resource Area Delineation. Conducted wildlife habitat evaluations and prepared Notices of Intent for pond management activities and residential development, including a wetland/stream roadway crossing.

Concord Country Club, Concord, MA
Delineated bank, bordering vegetated wetland, intermittent stream, isolated vegetated wetland, and vernal pool areas on the golf course property. Prepared a Notice of Intent for golf course restoration and improvements, and both a Notice of Intent and Special Permit Application for maintenance pond dredging.

A. D. Makepeace Property, Wareham/Carver/Plymouth, MA
On-going services associated with a mixed-use project on A.D. Makepeace land holdings totaling over 6,000 acres. Performed wetland delineations (bank, bordering vegetated wetland, isolated vegetated wetland, and Riverfront Area) and vernal pool assessments. Conducted historic research to determine the status of various irrigation canals in relation to Riverfront Area applicability. Prepared and submitted Abbreviated Notices of Resource Area Delineation, Requests for Determination of Applicability, Notices of Intent, and attended and presented at associated hearings and site walks with the Wareham Conservation Commission for various projects on the property, including commercial and residential development, solar arrays, park improvements, and a recretional boat launch. Also coordinated with the Natural Heritage & Endangered Species Program as applicable. Designed a wetland resource area mitigation site that included a 2,150 square foot bordering vegetated wetland replication, 175-foot long stream, and 113,270 square foot Riverfront Area restoration. Also coordinated the design of a 50,140 cf compensatory flood storage area. Prepared and submitted a Request for Special Review Procedure, Expanded Environmental Notification Form, Notice of Project Change, and Draft and Final Environmental Impact Reports to the MEPA office. Presently coordinating associated public meetings.

Francis Carter Preserve, Charlestown, RI
Conducted a vernal pool inventory/survey and delineated associated freshwater wetlands. Prepared Application to Alter a Freshwater Wetland to construct a boardwalk and viewing platform adjacent to the vernal pool, and to improve drainage in an existing parking area proximate to the wetland. The improvements have been constructed.

Elm Park Improvements, Worcester, MA
Prepared a Notice of Intent application relating to park site improvements proposed by the City of Worcester, including general site amenity improvements associated with pedestrian paths and the playground area, as well as repairing stone walls surrounding on-site ponds and removing accumulated sediment within the ponds.

University Park Improvements, Worcester, MA
Prepared a Notice of Intent application relating to park site amenity and safety improvements proposed by the City of Worcester, including the creation of a playground area, the installation of light fixtures and security cameras, and re-orienting pedestrian paths to create an alternative route adjacent to a portion of Crystal Pond. The latter path re-orientation required filling a portion of the pond to create a second pathway in a narrow portion of the park. On-site in-kind replication for Bank and Land Under Water Bodies and Waterways was included in the Notice of Intent.

Whitin Mill Redevelopment, Whitinsville, MA
Assisted with aquatic surveys required in association with the restoration of the mill's former hydropower.

Open Space & Recreation Plans, Cohasset, Bourne and Hanover, MA
Project manager for update of the Open Space & Recreation Plan in Cohasset. Responsible for natural resources components of the Open Space & Recreation Plan in Bourne. Performed environmental and municipal research for the Open Space & Recreation Plan in Hanover. In all towns, led and/or participated in focus group sessions, public input meetings, and presentations of the plans.

Permitting Analyses, Various, MA

Routinely evalutes projects to determine required permits, including analysis of methods to reduce permitting associated with specific projects. Performed such analysis in various municipalities including, but not limited to: Wareham, Carver, Scituate, Canton, Russell, Montgomery, Westfield, Concord, New Bedford, Southborough, Westborough, Natick, Sherborn, Framingham and Hingham, MA and Smithfield, RI.

Municipal Review Services, Various, MA

Provided peer review services for various projects in Plymouth, Wrentham, and Wellesley, MA. Assessed compliance with provisions, including performance stanards of the MA Wetlands Protection Act and local bylaws and regulations. Reviewed wetland delineations. Presented findings at associated hearings.

Environmental Site Assessments, Various, MA

Performed research, including review of DEP database, site reconnaissance and report preparation associated with Environmental Site Assessments for various properties in Wareham and Boston.

PRESENTATIONS AND PUBLICATIONS

Minihane, S. "Design of a Pilot Wetlands Mitigation Bank in Massachusetts" *Poster Presentation at the International Society of Wetland Scientists 2010 Annual Meeting*. Salt Lake City, Utah (June 27-July 2, 2010).

Las, E., **Minihane. S.**, & Miley. D., "A Pilot Wetlands Mitigation Bank in the Taunton River Watershed*" Association of Massachusetts Wetlands Scientists Newsletter*. Vol No 59 (October 2006): 8-9. Print.

Lichter, J., **Barron, S.**, Bevacqua, C., Finzi,A., Irving, K., Stemmler, E., & Schlesinger, W. "Soil Carbon Sequestration and Turnover in a Pine Forest after Six Years of Atmospheric CO_2 Enrichment" *Ecology* Vol No 86 (2005): 1835-1847. Print.

Barron, S. "Soil Carbon Sequestration in a Deciduous Forest Under Elevated Atmospheric CO_2 Concentrations" *Poster Presentation at the Ecological Society of America Meeting.* Savannah, Georgia (August 2003).

Barron, S. "Soil Carbon Sequestration in a Deciduous Forest Under Elevated Atmospheric CO_2 Concentrations" *Thesis Publication - Bowdoin College*. New Brunswick, Maine (2003).

Teegarden, G., Cembella, A., Capuano, C., **Barron, S.**, & Durbin, E. "Phycotoxin accumulation in zooplankton feeding on Alexandrium fundyense – vector or sink?" *Journal of Plankton Research.* Vol No 25 (2003): 429-443. Print.

Barron, S., Weber, C., Marino, R., Davidson E., Tomasky, G., & Howarth, R. "Effects of Varying Salinity on Phytoplankton Growth in a Low-Salinity Coastal Pond Under Two Nutrient Conditions" *Biological Bulletin.* Vol No 203 (Oct. 2002): 260-261. Print.

Weber, C., **Barron, S.**, Marino, R., Howarth, R., Tomasky, G., & Davidson, E. "Nutrient Limitation of Phytoplankton Growth in Vineyard Sound and Oyster Pond, Falmouth, Massachusetts" *Biological Bulletin*. Vol No 203 (October 2002): 261-263. Print.

Barron, S. "Effects of Varying Salinity on Phytoplankton Growth in a Low-Salinity Coastal Pond Under Two Nutrient Conditions" *Presentation at Scientific Symposium*. Woods Hole, Massachusetts (2002).

Barron, S. "Phycotoxin accumulation in zooplankton feeding on Alexandrium fundyense – vector or sink?" *Poster Presentation at Bowdoin College*. New Brunswick, Maine (2000-2001).

B+T provides ecological, design and permitting (federal, state, and local) services to successfully guide various aquatic resource restoration and creation projects. We also resolve wetland enforcement actions through appropriate mitigation and provide technical and regulatory support services to Conservation Commissions. Our multi-disciplinary staff provides a range of services including: wetlands and coastal resource area delineation, restoration and creation planning and design, flood studies, hydrologic and hydraulic modeling, wildlife habitat studies, water quality surveys, botanical surveys, GIS mapping, restoration monitoring, and federal, state and local permitting.

Charles River Wetlands Restoration, Millis, MA

Prepared wetland and bank restoration design plans as part of an enforcement order at a residential property located on the Charles River. The project involved restoration of over one acre of scrub shrub wetland that had been historically filled without necessary permits. The project also involved the stabilization and restoration of a portion of the bank along the Charles River that had also been developed. Consulted with the DEP during the design process to ensure that the design plans included sufficient wetland area and flood storage capacity.

Damde Meadows Salt Marsh Restoration, Hingham, MA

Performed delineation of coastal resource areas, conducted topographic and bathymetric surveys, and provided comprehensive permitting for the Trustees of Reservations to remove two existing culverts and perform dredging to create open channels leading to Hingham Harbor and to construct a bridge crossing at Worlds End Reservation. The project goals included salt marsh restoration and public safety improvements at the site. Removal of the outer culvert was completed as an emergency project, which required coordination with ACOE, NOAA, Massachusetts DEP, NHESP, MHC, DMF, CZM, MEPA, and the Hingham Conservation Commission. Also prepared post-construction filings associated with each emergency approval, which also included requests for the required permits associated with the second culvert, channel, and a new bridge.

Coolidge Point Stream Restoration, Manchester-by-the-Sea, MA

Provided coastal and wetland resource area delineation, land surveying, engineering design, and permitting services for restoration of a portion of the tidal creek connecting Clarke Pond to Kettle Cove at Coolidge Point for the Trustees of Reservations. The project involved the reduction of a hydraulic restriction at a pedestrian crossing over the tidal creek. The channel was widened and the existing footbridge was replaced with a new structure designed with a greater span. The project has resulted in increased capacity for tidal flow into Clarke Pond, restored Land Subject to Tidal Action, and reduced flooding of upland areas bordering Clarke Pond during significant rainfall events. Permitting was undertaken with ACOE, DEP, and the Manchester Conservation Commission. This restoration project is the first component of the long-term vision of further restoration of tidal flow to the Clarke Pond estuary system.

Bank Stabilization, Sagamore Creek/Neponset River ACEC, Quincy, MA

Provided design, permitting, and construction administration services to support tidal shoreline restoration efforts along Sagamore Creek in the tidal Neponset River estuary. Implemented bioengineering techniques to stabilize the eroding shoreline through the creation of a linear salt marsh, as opposed to armoring the bank with a rip-rap revetment. The design mimicked the slope of the healthy salt-marsh environment, and utilized coir logs with plantings and salt marsh grass biomats to stabilize the severely eroded shoreline area. Subsequent monitoring was undertaken, which included the establishment of vegetative transects and photopoints that were revisited during each monitoring field visit.

Shoppers World Wetland Enhancement, Framingham, MA

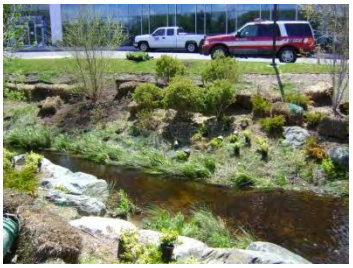
Coordinated and undertook permitting with the EPA, ACOE, MA DEP, and the Framingham Conservation Commission and provided a mitigation strategy to resolve the wetland issues caused by previous development. Designed a wetland enhancement area including a pedestrian pathway along the wetlands for citizens to access the area and enjoy the benefits of the rejuvenated natural resources.

Drainage Channel Enhancement Area, Raynham, MA

Designed and permitted a high-flow bioengineered drainage channel and wetland habitat creation area. Also prepared bid documents and technical specifications, assisted with contractor selection, and provided full construction administration services including oversight and guidance, as well as monitoring services subsequent to construction. The drainage swale has successfully conveyed flows from a 60-inch stormwater drainage pipe and has greatly improved pollutant removal from the associated roadway runoff.

Weston Corporate Center Stream Relocation, Weston, MA

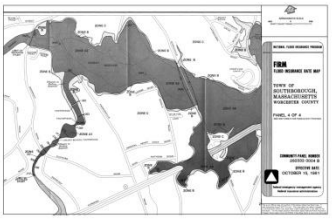
Provided environmental consulting and permitting services for the redevelopment of a 75-acre quarry site located at the interchange of Routes 20 & 128 in Weston. Designed a stream channel as a relocation of a man-made "stream" created during the site's quarry operations. The existing channel contained invasive vegetation and lacked a naturalized character. The new stream design was based upon hydrological modeling and flood profiling and included a more natural flow regime (incorporating a low flow channel) as well as native vegetation. Performed associated construction oversight and subsequent monitoring. Additionally, performed a study to assess the macroinvertebrate life and habitat conditions within the quarry ponds, and evaluated potential implications of a proposed cooling water withdrawal and discharge from the quarries.



Sheraton Hyannis Resort Wetland Basin, Barnstable, MA

Managed the design and permitting of a new wetland basin to control stormwater runoff from the hotel parking lot. Performed an as-built survey, wetland delineation, and drainage calculations to ultimately create the drainage measures needed for the parking facility.

Fay School FEMA Flood Study, Southborough, MA



Obtained historic flood study from FEMA and analyzed the model for several sub-basins within the Sudbury Reservoir waterway using HEC-RAS and HEC-2 modeling software. Identified errors with the official FEMA flood study and associated FIRM map. Prepared corrected flood study models and submitted to FEMA with request for map revision. Successfully obtained Letter of Map Revision from FEMA that reduced flood elevations within subject property by nearly two (2) feet.

Carding Mill Pond Dredging Feasibility, Sudbury, MA

Retained by the Hop Brook Protection Association to prepare a feasibility study for the dredging of the 41-acre Carding Mill Pond to improve water quality, restore fisheries habitat and control nuisance aquatic vegetation. Performed a wildlife habitat evaluation, bathymetric survey, and sediment depth survey. Prepared schematic design plans for hydraulic and conventional dry dredging options. Cost estimating and pre-application meetings with ACOE, DEP, DFW, and the Sudbury Conservation Commission are on-going.

Pilgrim Station Intake Channel Dredging, Plymouth, MA

Provided upland and bathymetric surveying, sediment sampling and analysis, engineering design, environmental permitting, construction administration and environmental monitoring services for the maintenance dredging of over 40,000 cubic yards of sediment from the plant's cooling water intake channel. Permitting was completed with the ACOE, DEP, MEPA, CZM and the Plymouth Conservation Commission.

Wight Pond, Dedham, MA

Performed a comprehensive ecosystem assessment of Wight Pond, including a bathymetric survey, pond substrate analysis, aquatic macrophyte identification, assessment of the fish population and health and water quality analysis. Pond restoration and management measures were developed and detailed in a comprehensive report to the client. We also prepared design plans and obtained permits from DEP and the Dedham Conservation Commission for hydroraking of nuisance aquatic vegetation.

Concord Country Club, Concord, MA

Designed, permitted and oversaw the dredging of two ponds intersected by Jenny Dugan Brook. The ponds were dredged to counteract the accumulation of sediment and associated eutrophication due to upstream agricultural operations. The quality of the aquatic habitat was improved and the opportunity for colonization by nuisance aquatic vegetation was reduced through the increased water depths. The creation of a sediment forebay within the upstream pond enhances settling of sediments and facilitates easier sediment removal in the future. In addition to dredging activities, dilapidated or crushed culverts connecting the ponds were replaced, a historic walking path was refurbished, and a pedestrian footbridge was installed. Permitting and coordination was completed with the ACOE, NHESP and the Concord Board of Appeals and Natural Resources Commission.

Private Residence, Woodstock, VT

Conducted a comprehensive ecosystem assessment of a pond, including a bathymetric survey, pond substrate analysis, aquatic macrophyte identification and mapping, assessment of the fish population and health and water quality analysis. Management recommendations were provided for improving pond habitat to support a recreational cold water fishery. Specifically, to improve recreational opportunities for swimming and trout fishing at the pond, we prepared plans and obtained approvals for development of a bedrock well for cold water inflow, installation of a benthic barrier to control nuisance aquatic vegetation, installation of a diffused aeration system, deployment of an ultrasonic algae control device, and dredging of sediment from within the pond. We performed successful SCUBA installation of 10,000 square feet of benthic barrier on the pond bottom to control nuisance aquatic vegetation. Permitting and coordination was required with the ACOE and VT DEC.

Wetlands Banking Pilot, Hanson, MA

Developed site evaluation criteria, community interest values and informational flyers to solicit and evaluate potential candidate sites within the Taunton River watershed. The 1600-acre Burrage Pond Wildlife Management Area was chosen as the most eligible candidate site. We completed topographic surveys, wetland delineation, subsurface soil evaluations, groundwater monitoring, hydrologic modeling, design plan preparation, cost estimating, value engineering, and permit documentation for the creation and revitalization of wetlands and streams that would comprise the wetland bank. The project design included over nine (9) acres of wetland creation and sixteen (16) acres of wetland/stream revitalization. The design was based on the following goals: wetland creation and revitalization within previously disturbed areas, diverse and distinctive habitats (forested, scrub-shrub, shallow and deep emergent), on-site turtle habitat, recreation, hydrologic effect on the remaining property, construction phasing and the utilization of buried hydric soils. Prepared and filed a Notice of Intent application with the Hanson Conservation Commission.

Private Residence, MA

Provided design and consulting services to establish a family estate on a 60-acre site. One of the more unique components of the project was the creation of a man-made synthetic-lined pond system. The pond system incorporates a 9-foot waterfall from a shallow ice-skating pond that cascades into a series of shallow pools that connect to a deep trout pond. A healthy ecosystem was successfully established within the pond system, such that trout have spawned and thrive, by integrating: cold water inflow, diffused aeration to maintain high dissolved oxygen levels, aquatic vegetation, and artificial spring-fed spawning beds for the trout. We provide guidance and oversight related to pond and fisheries management and maintenance on a continuous basis.

Old Town Hill Salt Marsh, Newbury, MA

Provided pro bono design and permitting services for the restoration of the Old Town Hill Salt Marsh which is part of the Old Town Hill Reservation, owned and maintained by The Trustees of Reservations. The goal was to restore tidal flows

to a more natural condition by improving flushing between the western and eastern portions of the salt marsh, restore disturbed areas, and prevent future degradation of the resource area. Cobblestone spillways were created in the gravel access road that improved the hydrologic connection between the salt marsh areas on both sides of the road. Parking area limits were defined with wooden posts to prevent vehicular parking in the salt marsh. The access gate was modified and a sign to direct pedestrian, horse, and bicycle traffic over the gravel road entrance was installed to decrease adverse effects to the salt marsh.

New Bedford Waterfront
New Bedford, MA

B+T has conducted services associated with the remediation of a contaminated boat slip in New Bedford Harbor for nearly 10 years. Initially retained specifically for mitigation-related services, our role expanded to include the permitting associated with the remediation project, as well.

B+T first conducted a feasibility study, and provided surveying, engineering, environmental, design, and permitting services to support salt marsh restoration in the Gifford Street boat ramp area of New Bedford Harbor, as part of the mitigation required for the filling of the contaminated boat slip. The original Gifford Street restoration site consisted of an historically filled area that was park land, but that had been subject to filling, dumping, and colonization by the invasive species common reed. Although B+T advanced design and permitting of a salt marsh restoration area that included a tidal creek and adjacent dunes, due to changes in the planned use of the Gifford Street property by the City of New Bedford, that location became unavailable for the mitigation project. Therefore, B+T performed a feasibility analysis of various other potential mitigation sites throughout the region, and, based upon coordination with various regulatory agencies and the City of New Bedford, identified the former Reliable Truss site (proposed Rivers End Park) as an ideal location for a salt marsh creation project.

B+T is currently undertaking services to design and prepare permits for a 15,000 sf salt marsh at Rivers End park, with input from the City of New Bedford since the City will ultimately construct the marsh as part of a park project at the site. We also prepared a cost estimate for the proposed design to assist the City in planning the project. The salt marsh design evaluated existing soils and vegetative communities at the site, and incorporates the deepening and widening of an existing channel to create a tidal creek leading from the Acushnet River into the creation area, allowing the tidal flushing necessary to promote the growth of salt marsh vegetation while minimizing impacts to existing salt marsh.

B+T also successfully completed the permitting for the boat slip remediation, which included 401 Water Quality Certification, Chapter 91 License, Notice of Intent, Notice of Project Change, and Army Corps of Engineers Category 2 Applications. Extensive coordination with regulatory agencies was undertaken to facilitate the process. The boat slip remediation was completed in late 2011. We also provided assistance during construction to ensure compliance with specific permit conditions, coordinated required monitoring upon completion, and is currently processing the associated Requests for Certificate of Compliance.

In June 2012 B+T was awarded the **Environmental Business Council Nicholas Humber Environmental Award for Outstanding Collaboration** *in recognition of the outstanding public-private partnershiop resulting in the expedited and innovative remediation of the New Bedford Boat Slip MGP Site*.

Client

Lightship Engineering, LLC

Services

Resource Area Mapping

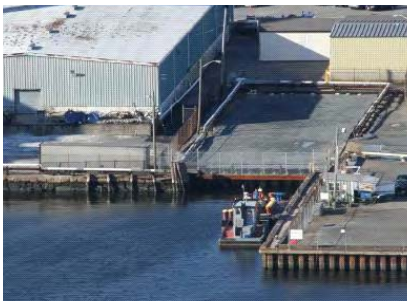
Civil Engineering

Cost Estimating

Environmental

Permitting

Survey



Completed boat slip remediation

Rivers End Park site

Yankelovich Property Coastal Bank Stabilization
Wellfleet, Massachusetts

B+T was retained to assist with the permitting of a coastal bank stabilization project along Wellfleet Harbor. The project site was experiencing severe erosion, largely due to 2,800± linear feet of updrift stone revetment. Because the project site was located within priority habitat for endangered species, significant coordination with the Natural Heritage and Endangered Species Program (NHESP) was required to ensure a net benefit was provided to the downdrift endangered species habitat.

The on-site erosion was increasing exponentially and it became apparent that the coastal bank may be lost if it were exposed to a significant storm. B+T undertook emergency permitting with NHESP and the local Conservation Commission to allow for implementation of a temporary pile wall should it become necessary to protect the coastal bank while the full stabilization was undergoing the permitting process.

Due to the significant and severe nature of the on-site erosion, it was necessary to begin construction of the stone revetment as soon as possible to avoid further damage to the property and potential loss of the house and septic system. B+T undertook an extremely aggressive schedule to prepare and submit the permit applications and plans, as well as exhaustive coordination with municipal officials to facilitate receipt of the permits within the designated schedule.

The full stabilization required local and state permitting including Notice of Intent, Massachusetts Department of Environmental Protection (MA DEP) 401 Water Quality Certification, MA DEP Chapter 91 Waterways License, NHESP Conservation and Management Permit, Army Corps of Engineers (ACOE) Category 2 General Permit, and Massachusetts Historic Commission (MHC) Project Notification Form.

Client

Yankelovich Wellfleet 1999 Trust Agreement

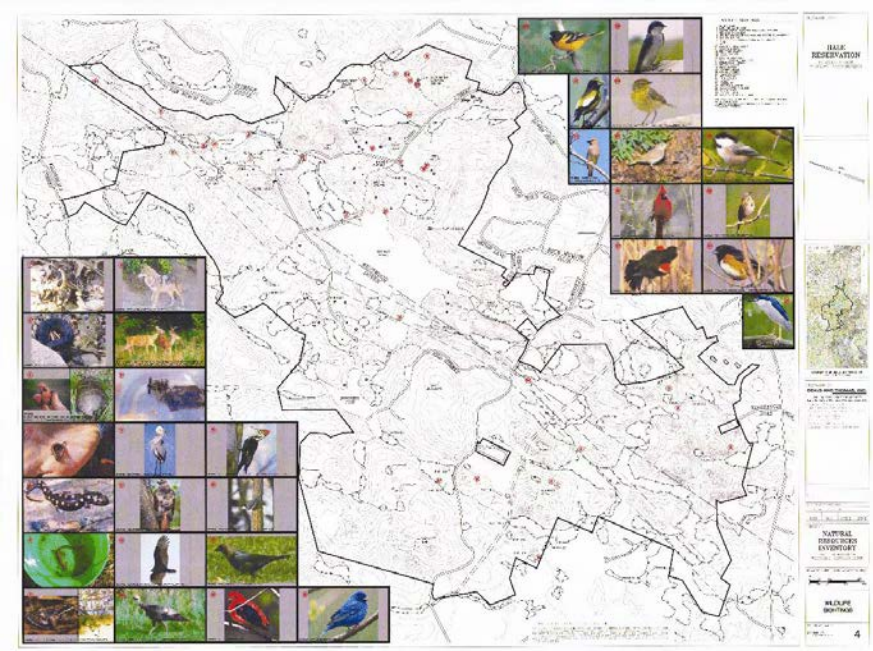
Services

Survey

Permitting

B+T worked with the Hale Reservation to catalogue, photograph, and map the various natural resource features on-site. The information will be utilized by Reservation staff and the Board of Directors to aid in the management of programs and the stewardship of this remarkable property. The extensive investigation used both existing studies and additional observations to create a report describing the various woodlands, wetlands, ponds, fields, and wildlife habitat present on the Reservation. The report comprises the Natural Resources Inventory portion of Hale Reservation's Master Plan.

The report described attributes of the land in detail, paying special attention to the water quality of ponds and wells. It also documented the status of both plant and animal species on the reservation. B+T outlined management opportunities for Hale Reservation, including recommendations for the control of invasive species, maintenance of trail systems, water quality management, and septic systems. The comprehensive guidance to the Hale Reservation encouraged the use of an action plan, coordination with adjacent conservation landowners, educational initiatives, and proper allocation of resources to result in effective stewardship of this regionally significant property.



Client
Hale Reservation

Project Data
1,100 Acres

Services
Natural Resource Inventory & Management Considerations

ATTACHMENT E

New Bedford Marine Commerce Terminal
Mitigation Implementation Schedule

ID	Task Name
1	NTP Issued to Cashman-Weeks NB
2	**Winter Flounder Construction**
3	Dredge Bottom of CAD 3 and Cap Winter Flounder
4	Dredge Intermediate Footprint and Cap Winter Flounder
5	**Winter Flounder Monitoring**
6	Post Construction Monitoring Year 1
7	Post Construction Monitoring Year 2
8	Post Construction Monitoring Year 3
9	Post Construction Monitoring Year 4
10	Post Construction Monitoring Year 5
11	Potential Post Construction Monitoring Year 6
12	Potential Post Construction Monitoring Year 7
13	<New Task>
14	**OU#3 Capping and Intertidal Habitat Restoration**
15	Capping and Construction
16	**OU#3 Capping and Intertidal Habitat Restoration Monitoring**
17	Post Construction Monitoring Year 1
18	Post Construction Monitoring Year 2
19	Post Construction Monitoring Year 3
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24	**Tern Surveys**
25	Survey
26	Reporting
27	**Rivers End Park**
28	Procurement
29	Construction
30	Post Construction Monitoring Year 1
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35	Potential Post Construction Monitoring Year 6
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37	**Shellfish Seeding**
38	Shellfish Seeding Year 1
39	Shellfish Seeding Year 2
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42	Shellfish Seeding Year 5
43	Shellfish Seeding Year 6
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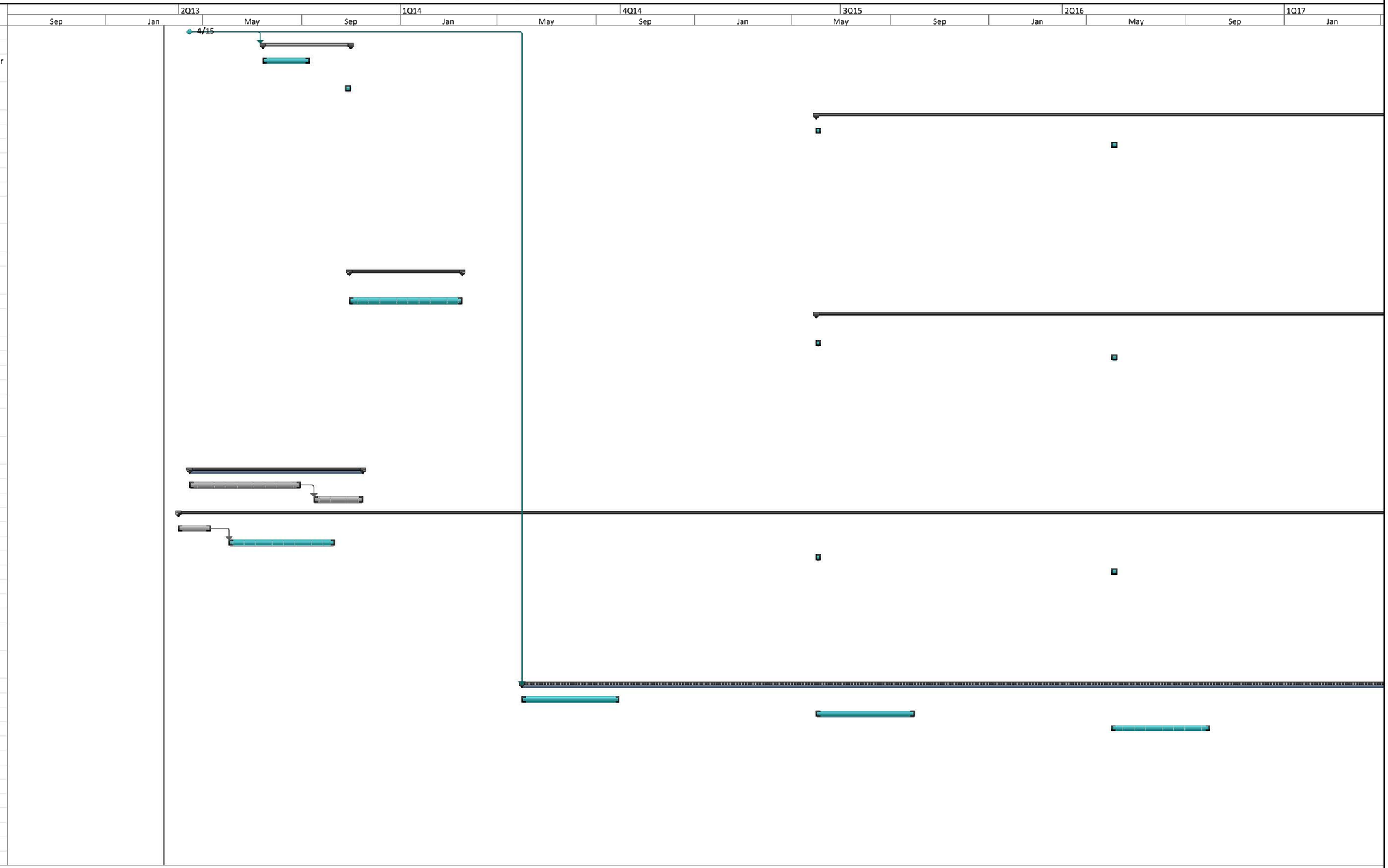
45	Shellfish Seeding Year 8
46	Shellfish Seeding Year 9
47	Shellfish Seeding Year 10
48	Potential Shellfish Seeding Year 11
49	Potential Shellfish Seeding Year 12



Project: Gant Chart
Date: Wed 3/20/13

Task		Summary		External Milestone		Inactive Summary		Manual Summary Rollup		Finish-only			
Split		Project Summary		Inactive Task		Manual Task		Manual Summary		Deadline			
Milestone		Completed Tasks		Inactive Milestone		Duration-only		Start-only		Progress			

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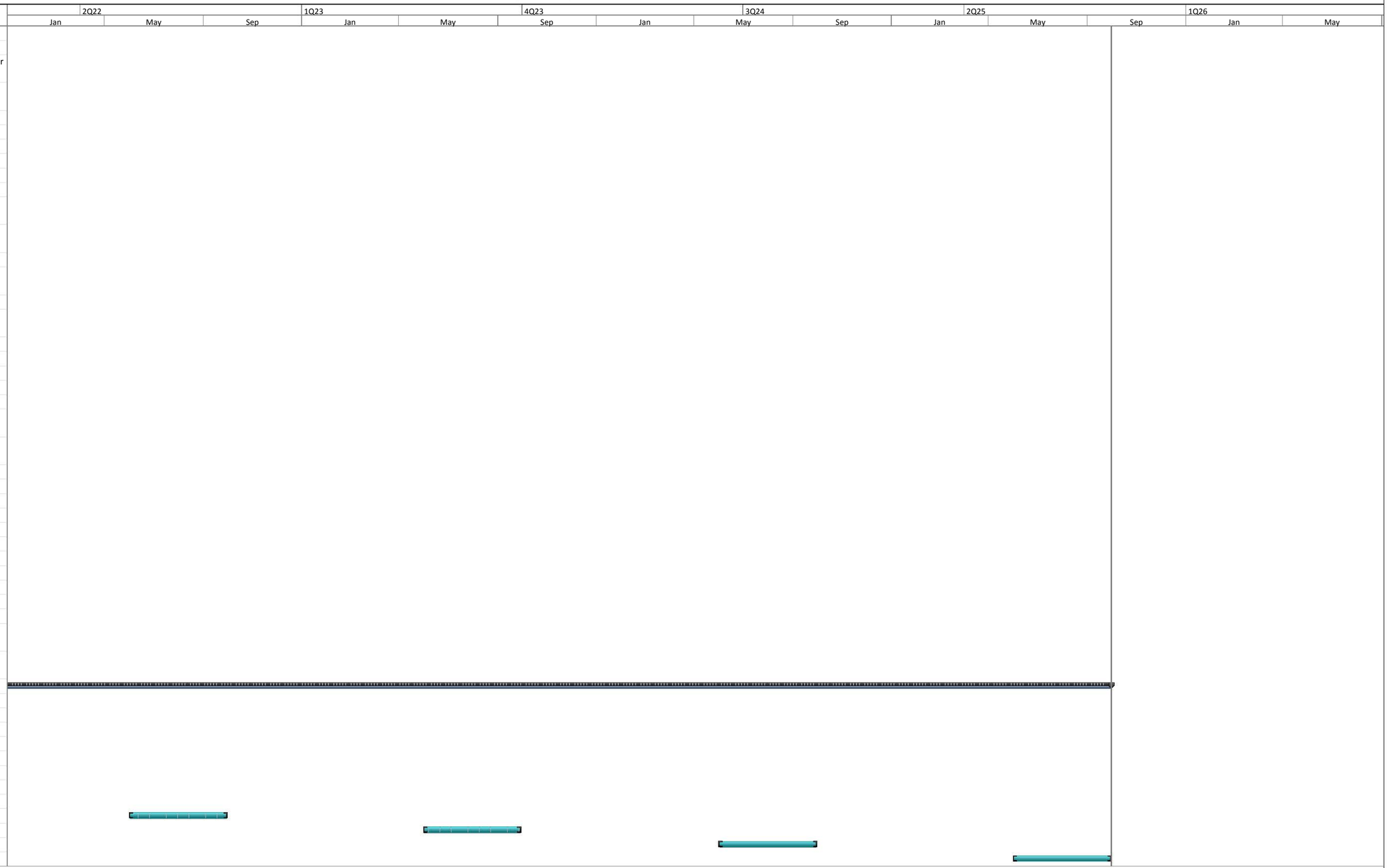

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