

## **Harwich artificial reef site assessment**

### **Introduction**

The creation of artificial reef habitat has been employed by many coastal states as an effective method of increasing fisheries productivity, augmenting fisheries habitat, and enhancing local recreational fisheries (Ditton et al. 2002; Figley 2004). The Division of Marine Fisheries (DMF) has an established artificial reef program designed to provide an operational framework for responsible long-term management of artificial habitats that provide benefits to fisheries resources. Nantucket Sound is an area of limited hard bottom habitat relative to other coastal regions of Massachusetts. Bugley and Carr (1994) reviewed the status of artificial structures in Nantucket Sound and found many of the once plentiful shipwrecks were deteriorating, resulting in an overall loss of relief and habitat value. Public interest in developing artificial reefs in the region has grown over concerns that the amount of available structured fish habitat along southern Cape Cod is diminishing.

DMF conducted a site assessment to examine the potential for artificial reef development in state waters off the coast of Harwich in Nantucket Sound. Sidescan sonar and diver transect data were collected in 2009 and 2010 from an area identified using exclusion mapping. Data were also collected from an existing artificial reef in state waters off the coast of Yarmouth for comparative purposes (Figure 1). A modification of the protocol established by Barber et al (2009) for selecting an artificial reef site in Boston MA was utilized for this assessment.

### **Methods**

#### **Exclusion mapping**

Seven general criteria were used to determine an optimal location to assess for potential artificial reef development (Table 1). Prior to collecting field data, DMF employed an exclusion mapping method (see Barber et al., 2009) to identify and eliminate areas unsuitable for reef development. Existing information, including NOAA charts and GIS data were reviewed for this analysis.

Table 1. Criteria for selecting a site for artificial reef deployment

Criterion	Description
accessibility	Area is suitable for safe small boat operation and recreational use and does not interfere with commercial vessel traffic.
depth and wave action	Water is deep enough to protect the reef from wave action. Targeted depth range was between 26 and 40 feet.
established habitats	Avoid existing established habitats.
substrate	Substrate consists of firm sediment types that provide a stable platform for approved materials.
slope	Sites with slopes less than 5° are needed for reef stability.
water quality	Low turbidity, low siltation rate, and adequate light penetration.
user conflicts	Avoid potential conflicts with other user groups, including ferry routes, weir fisheries, and other commercial and recreational fishing activities.

### *Accessibility*

Site accessibility was determined based on the distances recreational boaters would be required to travel from local ports. Charter boats originating from Saquatucket Harbor were witnessed on the Yarmouth reef site, over seven miles from port, on several occasions. Based on these observations, all areas within the 3-mile Harwich jurisdictional limits were determined to meet this criteria.

### *Depth and wave action*

Depth data were analyzed using NOAA chart #13237 and available bathymetry data from MassGIS. Depth data was collected during diver transect surveys and calibrated for actual mean low water (MLW) using local tide data available from NOAA. Charted depths between 26 and 40 feet (MLW) were considered for site evaluation.

### *Established habitats*

A substantial amount of area within Harwich coastal waters is designated as habitat suitable for shellfish, specifically quahog and surf clam, according to data published by DMF and MassGIS. This information includes sites where shellfish have been observed since the mid-1970's, but may not currently support any shellfish. Therefore, these designations represent potential rather than actual shellfish habitat areas. Site-specific surveys are necessary to ascertain current distribution and abundance of shellfish species. As such, additional information was required in order to make a site-specific assessment on established habitats. This factor was addressed by collecting information on the presence of shellfish species during diver transect survey.

### *Substrate*

Initial substrate data analysis consisted of a review of navigational hazards, rock outcrops, and other relevant information depicted on NOAA chart #13237 and data available from Mass GIS. There is limited published information available in finer scale resolutions on the surficial substrate composition of the seafloor in the Harwich region of Nantucket Sound. Further, substrate composition is one of the most critical components when selecting a suitable location to deploy an artificial reef. Therefore, sidescan sonar and diver transect survey data are the primary sources of information used in this assessment.

### *Slope*

Slope data reviewed from soundings measurements listed on NOAA chart #13237 and bathymetry data from MassGIS were used to select an assessment area with a slope of  $<5^\circ$ . Slope was verified by collecting depth data at 10m intervals along each diver transect and calculating slope from observed depth changes over the total length of each 100m transect.

### *User conflicts*

Within the jurisdictional limits of the Town of Harwich, uses that could present potential conflicts for siting an artificial reef were avoided. Available GIS data including mapped navigational ferry routes, weir fisheries and identified commercial and recreational fishing uses were considered when selecting an appropriate location for further assessment.

Using these criteria, a 1.15 (735 acres) square mile of area located 1.5 nautical miles south of Saquatucket Harbor (Figure 1) was identified for further assessment using sidescan sonar and diver transect surveys.

### Sidescan Sonar survey

In August 2009, DMF contracted American Underwater Search and Survey (AUSS) to perform a sidescan sonar survey of the area identified through exclusion mapping. The tire reef site off the coast of Yarmouth was also assessed to compare the characteristics of a potential site in Harwich to an existing artificial reef. From this survey, a mosaic image (Figure 2) was generated to depict characteristic differences in surficial substrate. Visual analysis of image data generated from the sidescan sonar survey was used to identify locations for diver surveys.

### Diver surveys

Diver surveys were conducted to verify the composition of surficial substrate at locations selected from mosaic imagery analysis. Twenty-four out of twenty-eight identified locations were surveyed at the Harwich site in October 2009 and October 2010 (Figure 2). (Note: transect #'s 11,19,22,29 listed in Figure 2 were not surveyed). Divers quantified substrate types along both sides of a central transect line out to a distance of 2 meters. Larger substrate types were visually classified according to categories defined by Wentworth (1922 – Wentworth scale) and verified using rulers. Finer substrates were categorized as sand, mud, or silt. Primary (area contained >50% of sediment type) and secondary (area contained 10-50% of sediment type) sediment types were recorded at 10m intervals. Divers also collected data to qualitatively assess relative abundance and diversity of macroinvertebrates and vertebrates along each transect.

### Weighting and ranking analysis

A weighting and ranking analysis modified from Barber et al (2009) was utilized to assess field data for selecting a site location. Criteria included primary substrate percentage, depth, and proximity to other locations with suitable primary substrate composition. For each potential site, a numerical score was assigned to each category (Table 2).

Table 2. Reclassification values for substrate and depth

Primary surficial substrate			Rank value
silt	unsuitable	not capable of supporting reef weight	0
bolder / cobble	unsuitable	existing hard bottom habitat	0
sand/silt	potential	sediment reworking	1
sand / granule / pebble	prime		2
Depth			Rank value
<30 ft	unsuitable	navigational concerns, wave action	0
30 ft - 35 ft	prime		2
>35 ft	potential	reduced time for recreational divers	1

## Results

### Slope and wave action

Slope was calculated from the change in depth along 100m diver transect surveys. Barber et al (2009) used a 5° change in slope to eliminate potential sites because of concerns with reef stability. Slope calculations did not exceed 1° at any location within the surveyed area. There were no sand wave / ripple areas witnessed on any of the 24 diver transects sampled.

**Depth verification**

Depth data (Table 3) was collected *in situ* on all diver transect surveys at 10m intervals and averaged for each transect. Depth data was standardized to a mean low water (MLW) value by synchronizing the time of depth measurement to local tide data available from NOAA. Once adjusted to MLW values, seven transect locations (sites #16, 17, 20, 21, 23, 25, 26) were determined to be unsuitable based on the weighting and ranking analysis criteria.

**Primary substrate composition**

The results of the surficial substrate composition are listed in Figure 3 and includes transects 1 through 7 collected at the Yarmouth tire reef site for comparative purposes. Transects where >50% of primary substrate was identified as silt were eliminated as potential sites because of their inability to support the weight of reef materials. This eliminated all transects within the deeper section of the survey area (sites # 8,9,10, 12, 13, 14, 24), three of the nine sites within the middle survey region (sites # 15, 26, 30) and four sites within the shallower region (site #'s 17, 18, 20, 31). Site # 35 was also eliminated as a potential reef site as it was outside the survey area. Transect sites were then ranked by adding the depth and primary substrate ranking scores (Table 3).

Table 3. Reclassification rankings (see table 2) for each transect.

Site ID	Depth (MLW)	Depth rank	Primary substrate	Primary Substrate rank	Total (depth rank +primary substrate rank)	Rank Total*
8	33.4	2	Soft sand / silt	0	2	2
9	33.8	2	Soft sand / silt	0	2	2
10	33.8	2	Soft sand / silt	0	2	2
12	34.0	2	Soft sand / silt	0	2	2
13	34.0	2	Soft sand / silt	0	2	2
14	32.3	2	Soft sand / silt	0	2	2
15	31.0	2	Soft sand / silt	0	2	2
16	26.0	0	Sand	2	2	2
17	29.3	0	Soft sand / silt	0	0	4
18	31.5	2	Soft sand / silt	0	2	2
20	28.4	0	Shell debris/shack	1	1	3
21	25.3	0	Sand	2	2	2
23	27.4	0	Sand	2	2	2
24	33.7	2	Soft sand / silt	0	2	2
25	29.9	0	Sand	2	2	2
26	29.1	0	Soft sand / silt	0	0	4
27	30.0	2	Sand	2	4	1
28	31.3	2	Sand	2	4	1
30	35.1	1	Soft sand / silt	0	1	3
31	36.9	1	Soft sand / silt	0	1	3
32	31.2	2	Sand	2	4	1
33	30.8	2	Sand	2	4	1
34	30.8	2	Sand	2	4	1
35	32.0	2	Soft sand / silt	0	2	2

\*Sites ranking >1 were eliminated as potential sites

### Final site selection

Five transects (27, 28, 32, 33, 34) all exhibited primary substrate characteristics resembling the primary substrate data collected from the Yarmouth artificial reef site (see Figure 3, transects 1-7) and exhibited depth values of potential or prime based on weighting and ranking analysis criteria. To select the most optimal location for reef development, a “nearest neighbor” analysis was conducted by dividing the assessment site into 200m<sup>2</sup> block grid and selecting blocks within the grid where transect surveys were conducted (Figure 4A). Blocks within the grid where no transect data was collected and grid blocks containing transects eliminated during the weighting and ranking analysis were eliminated from consideration for site selection (Figure 4B). Two sites (site 27 and 34) were located adjacent to other sites that also scored high in the ranking analysis (Figure 4C). Site 27 was selected as the target area for permitting.

Site ID	Rank	# of adjacent ranked sites	Rank
27*	1	2	1
28	1	1	2
32	1	1	2
33	1	1	2
34	1	2	1

\* selected location (Figure 5).

#### *Species presence and relative abundance*

Divers quantified all fish species, motile invertebrates, and select sessile macroinvertebrates along both sides of a 100m transect. Relative abundance of observed species was totaled from both divers for each site. Survey totals for observed fish species for transects from the five top ranking sites are depicted in Table 5 and Figure 6. Survey totals for observed invertebrate species for transects from the five top ranking sites are depicted in Table 6 and Figure 7. Fish presence was recorded in only 2 instances among the remaining 5 top ranked transects and included only 2 fish species, black sea bass and cunner. There were six different fish species recorded among all transects within the Harwich survey area, compared to eleven fish species recorded at the Yarmouth site.

For invertebrates, ten species were recorded among the top five ranked sites, and 23 invertebrate species were recorded from all transects. A notable observation from site 27 included a large, patch of adult sized sea scallops along the sample transect. Several hundred individuals were found in dense concentrations along a section 20 – 30m in length and approximately 10m in width. No other animals could be located outside of this patch in any direction. Sea scallop densities of this magnitude are not known to occur in this location, and the presence of sea scallops, individual occurrences or large densities, were not noted at any of the 23 other transects sampled. It was determined that their occurrence in this location must be incidental

Slipper shells (*crepidula sp*) were also recorded in dense, patchy areas in four of the five ranked sites. Live animals along with shell “shack” comprised between 10 and 20% of the surficial substrate in these areas, however classification of live animal vs. shell only was not assessed.

*Crepidula sp.* require a hard object for attachment to the bottom during their larval settling stage, indicating surficial substrates where they are found are comprised of sediments where grain sizes are equal to or greater than sand.

### **Recommendations**

There is considerable variation in published literature regarding the optimal size for an artificial reef site. While larger permitted sites are capable of handling larger quantities of materials, smaller reef sites have been found to have proportionately higher fish densities due to a higher perimeter to area ratio (Ambrose and Swarbrick 1989). Further, smaller reef sites are more appropriate when limited information of the efficacy of reefs in a certain location is available. For this reason, an area of less than 10 acres should be considered when selecting the size of an area for permitting.

Primary substrate of the proposed site is similar in depth and composition to the established artificial reef in Yarmouth, which is located approximately 5.5 miles to the east. The Yarmouth artificial reef site continues to act as valuable fisheries habitat and has remained relatively stable and functional for over 30 years. Local recreational anglers actively use this site throughout the recreational season and were observed on site during all phases of data collection.

Settlement of deployed materials can be expected to occur over time, and must be considered when selecting new materials for deployment. The addition of new reef material to any site shall be in accordance with the "Guidelines for Marine Artificial Reef Materials, Second Edition" (ASMFC 2004), the National Artificial Reef Plan (NOAA 2007), the Massachusetts Artificial Reef plan (Rousseau 2008), and follow the materials and design criteria outlined in this document (see Appendix A). It is recommended that materials placed on site have a vertical profile of six feet or less to avoid potential impediments to navigation in the area.

Squid eggs, or mops, were noted along several transects during October sampling. Squid are known to be present in Massachusetts waters, specifically Nantucket Sound and Vineyard Sound from late April or early May and remain throughout the summer and fall. Artificial reef site development in this area shall be officially recorded on updated NOAA charts and in accordance with NOAA guidelines to avoid potential gear hangs resulting from the addition of reef materials to the area. Additional requirements including but not limited to time of year restrictions to avoid impacts to commercially and recreationally important marine species, monitoring, and best management practices for on-site construction activities may also be required from resource agencies during permitting and should be considered during the development of the construction phase.

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Figure 1.

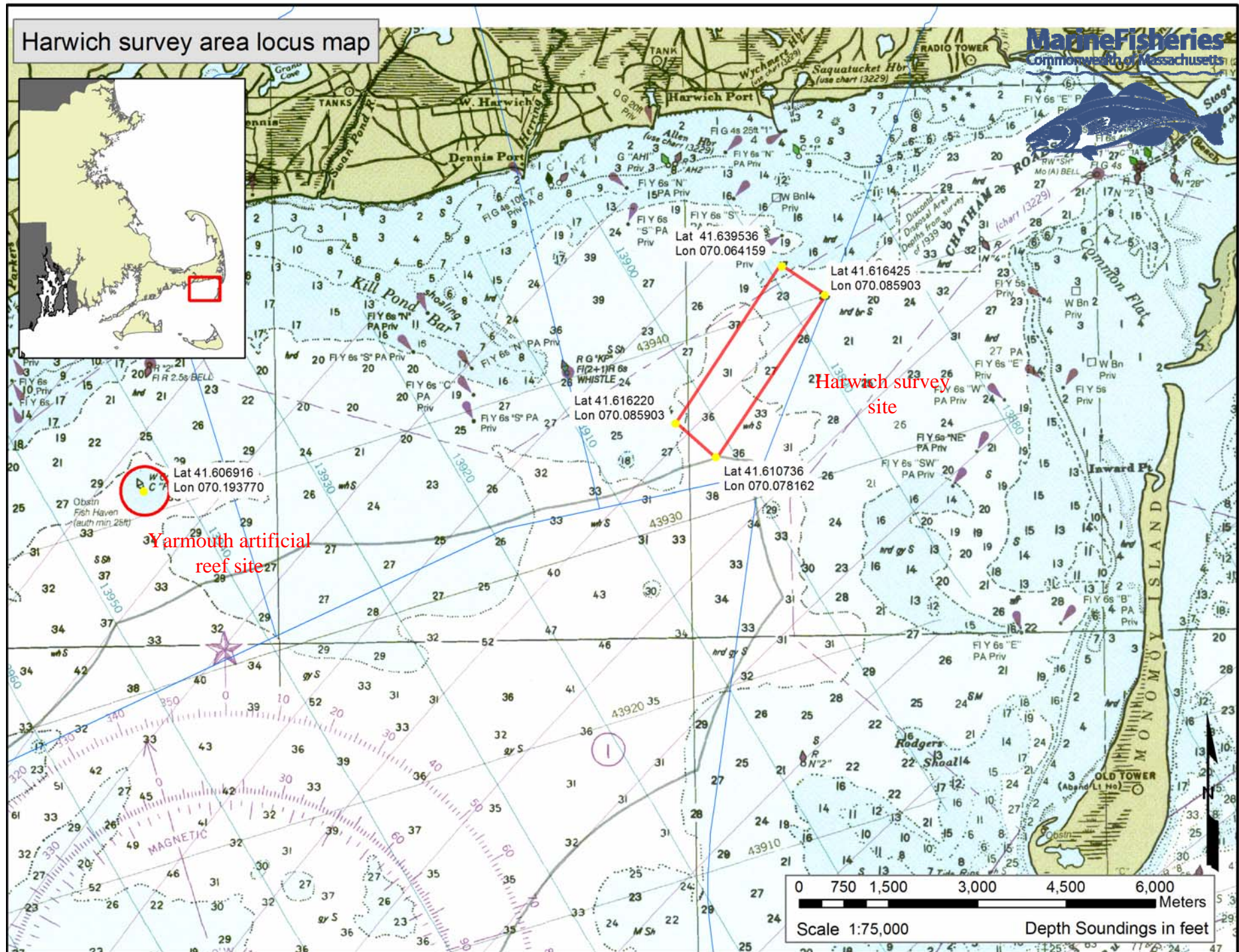


Figure 2. Survey site location including sidescan survey mosaic generated from sidescan survey and diver transect locations.

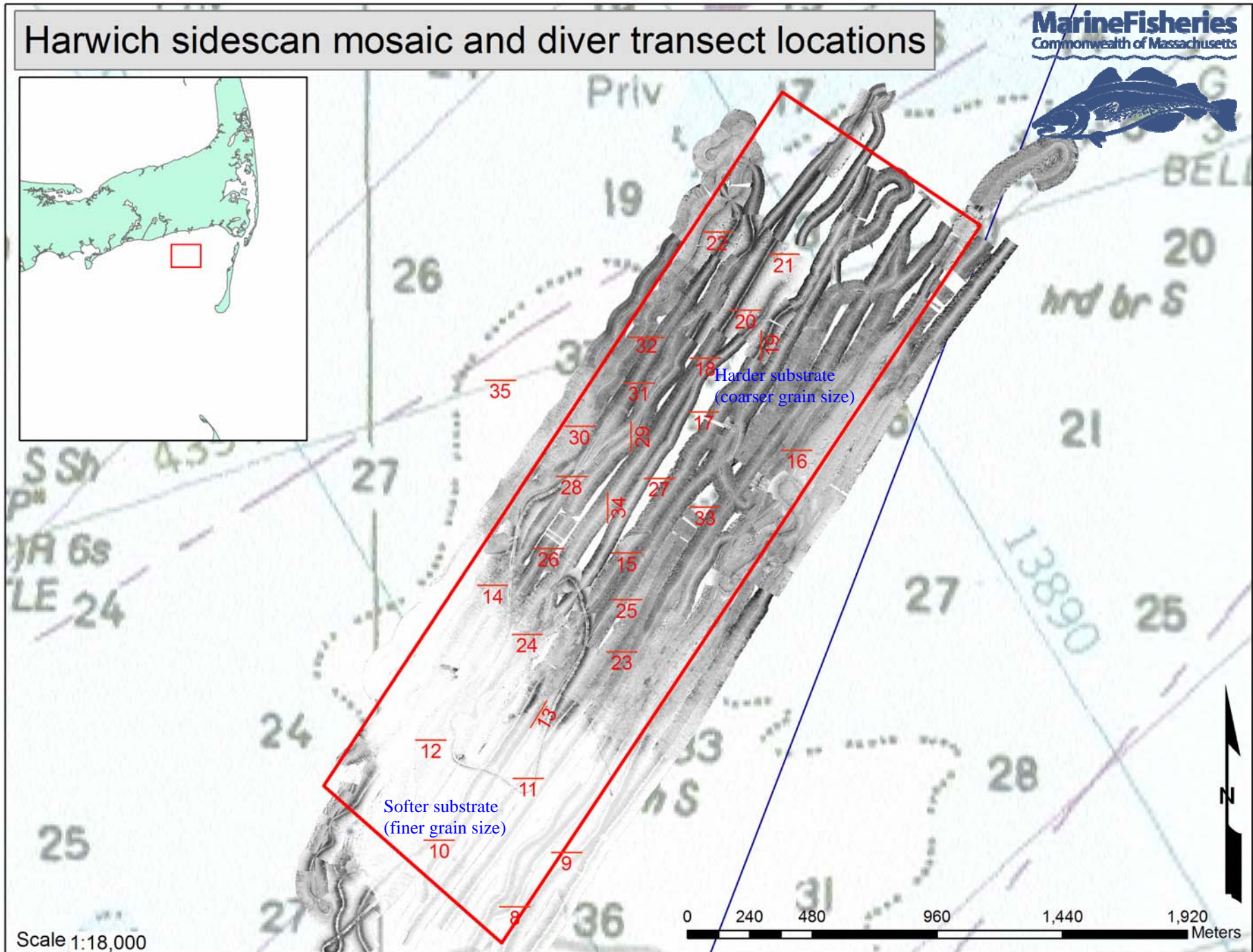


Figure 3. Surficial substrate composition (Transects 1-7 contain information collected from the Yarmouth artificial reef site for comparative purposes).

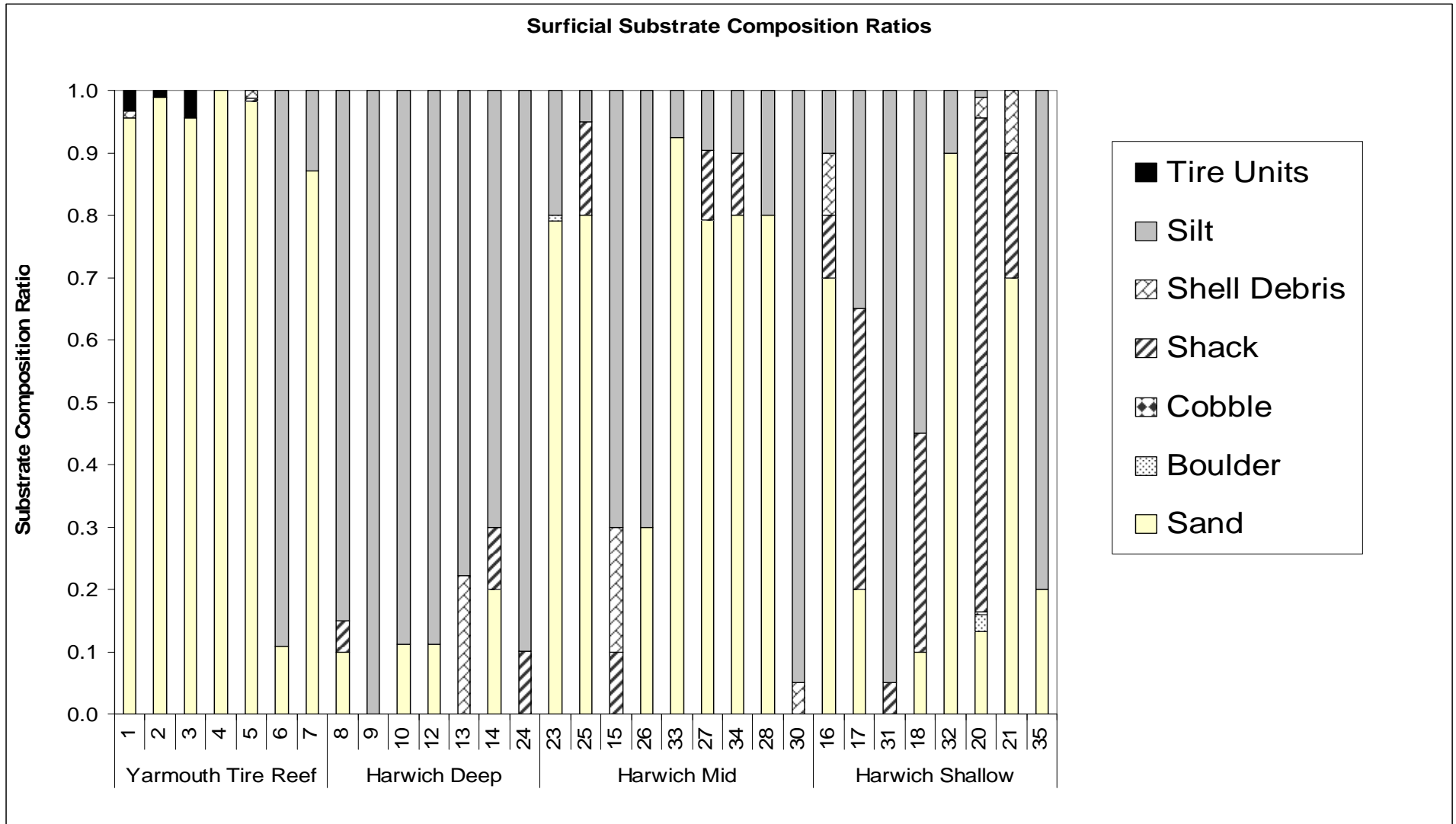


Figure 4. Schematic for selecting the most optimal location for reef site based on primary surficial substrate analysis.

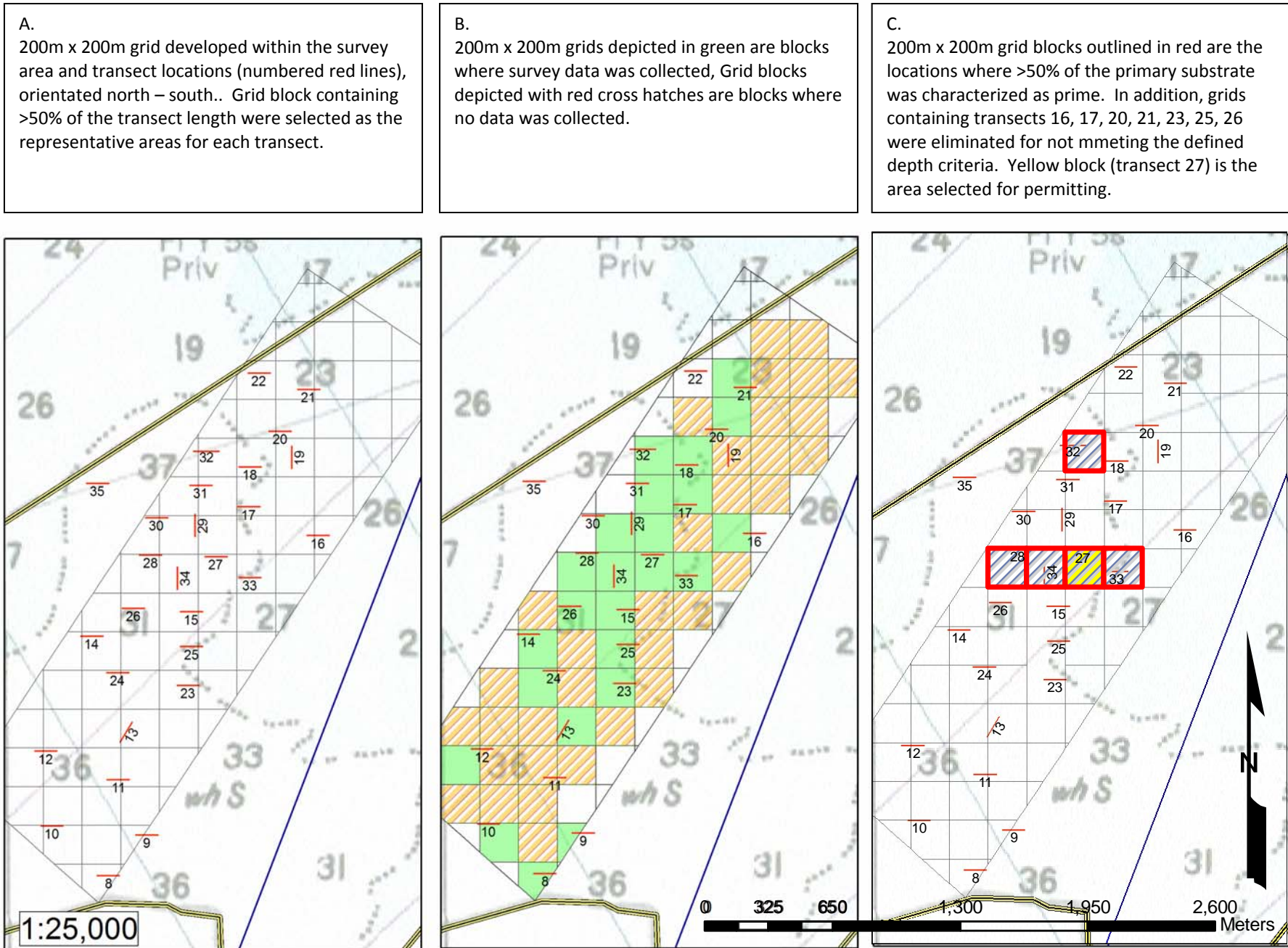


Figure 5. Locus map for Harwich reef.

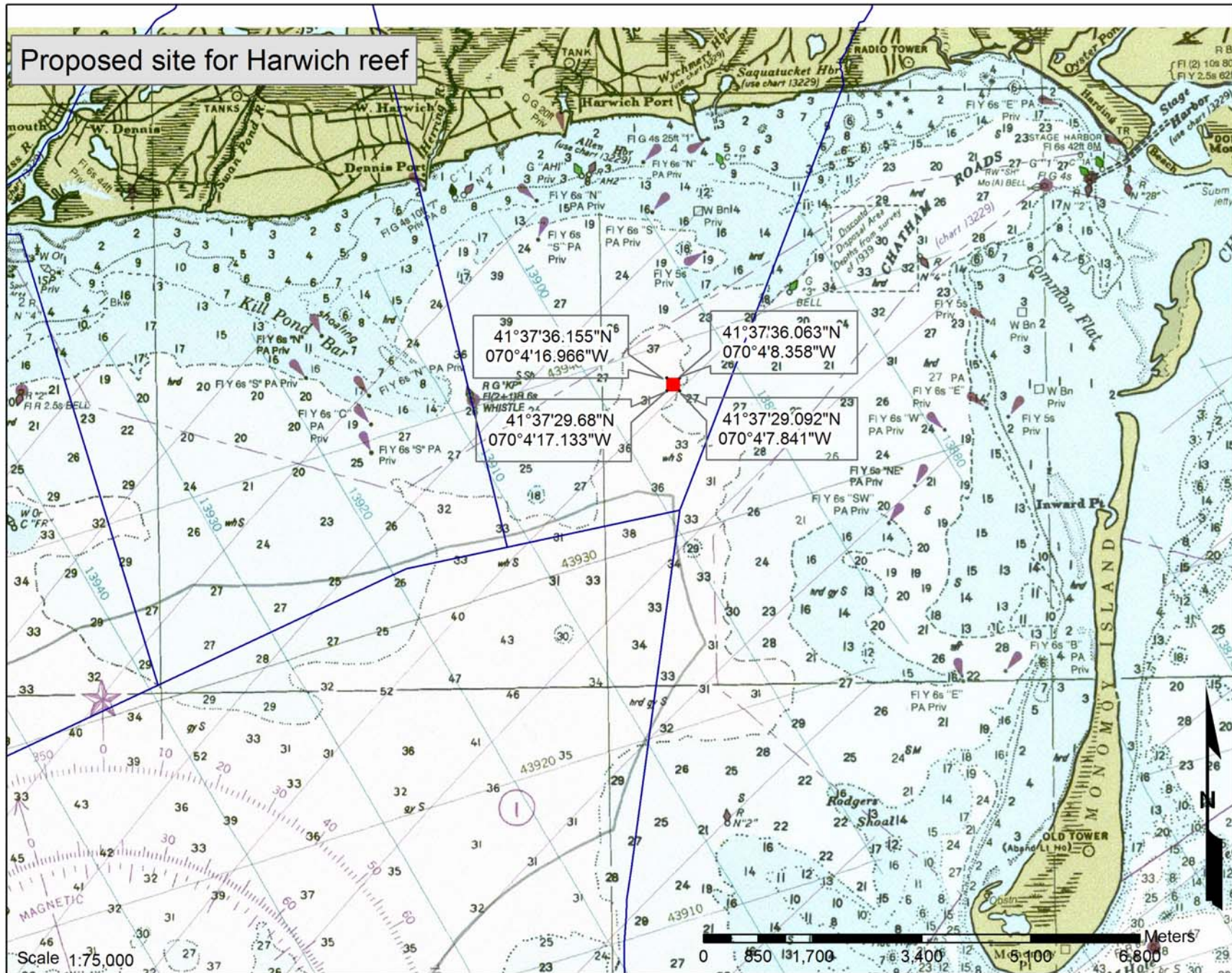


Table 5. Fish data

Fish (count)	T27	T28	T32	T33	T34	Totals
Black sea bass	2	0	0	0	0	2
Scup	0	0	0	0	0	0
Cunner	0	0	0	2	0	2
Winter flounder	0	0	0	0	0	0
Summer flounder	0	0	0	0	0	0
Tautog	0	0	0	0	0	0
Blue Runner	0	0	0	0	0	0
Lesser amber jacks (juv.)	0	0	0	0	0	0
butter fish	0	0	0	0	0	0
Spotfin butterfly	0	0	0	0	0	0
Northern sea robin	0	0	0	0	0	0
Red Hake	0	0	0	0	0	0
Totals	2	0	0	2	0	4

Figure 6. Fish counts by transect

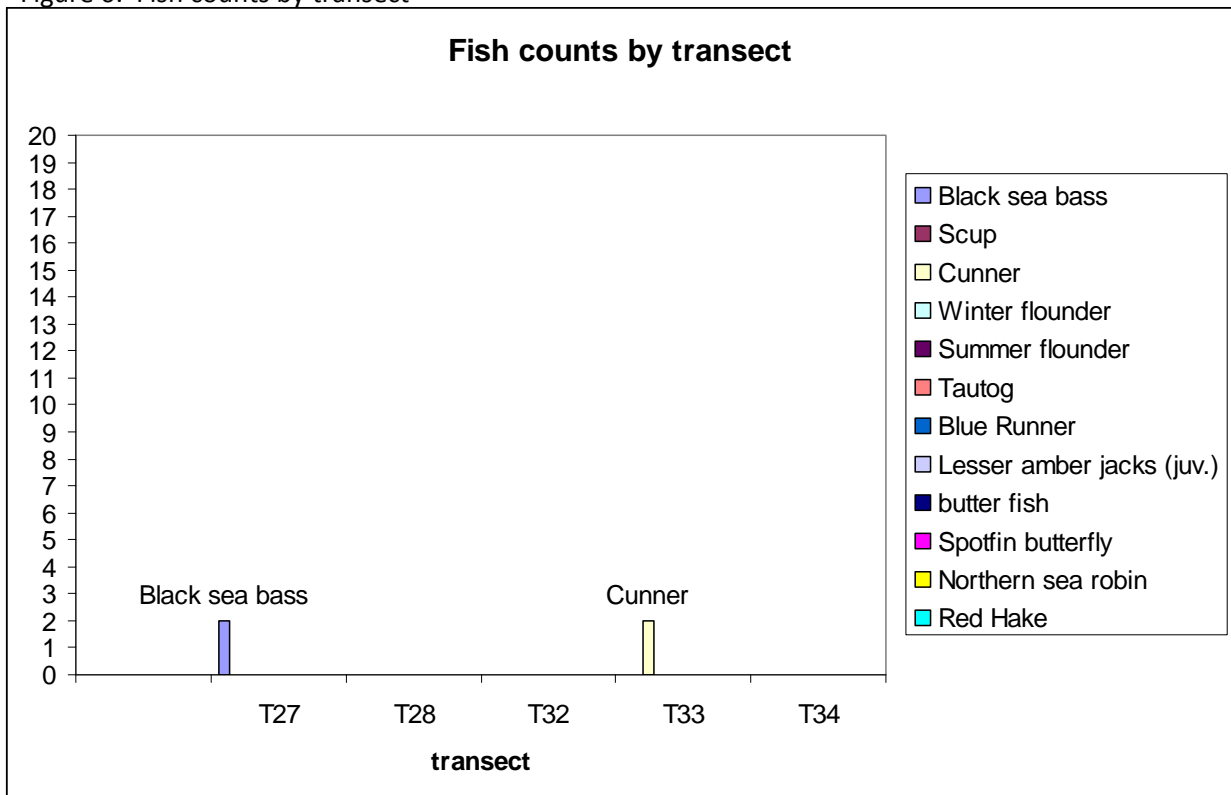


Table 6. Invertebrate data

Invertebrates (count)	T27	T28	T32	T33	T34	Totals
Hermit crabs	29	19	3	20	24	95
Libinia emarginata ( spider crab)	16	7	7	14	29	73
Cancer sp. (Rock and Jonah)	6	0	3	10	14	33
Busycon + Buccinum (whelks)	1	0	7	5	1	14
Neopanope mud crabs	0	0	0	1	1	2
Horseshoe crab	3	1	1	0	5	10
Lady Crab	0	0	0	1	0	1
Metridium sp. (anemonies)	2	14	0	10	2	28
Homarus americanus	0	0	1	0	0	1
Sea Scallop	356	0	0	0	0	356
Totals	413	41	22	61	76	613

Figure 7. Invertebrate counts by transect

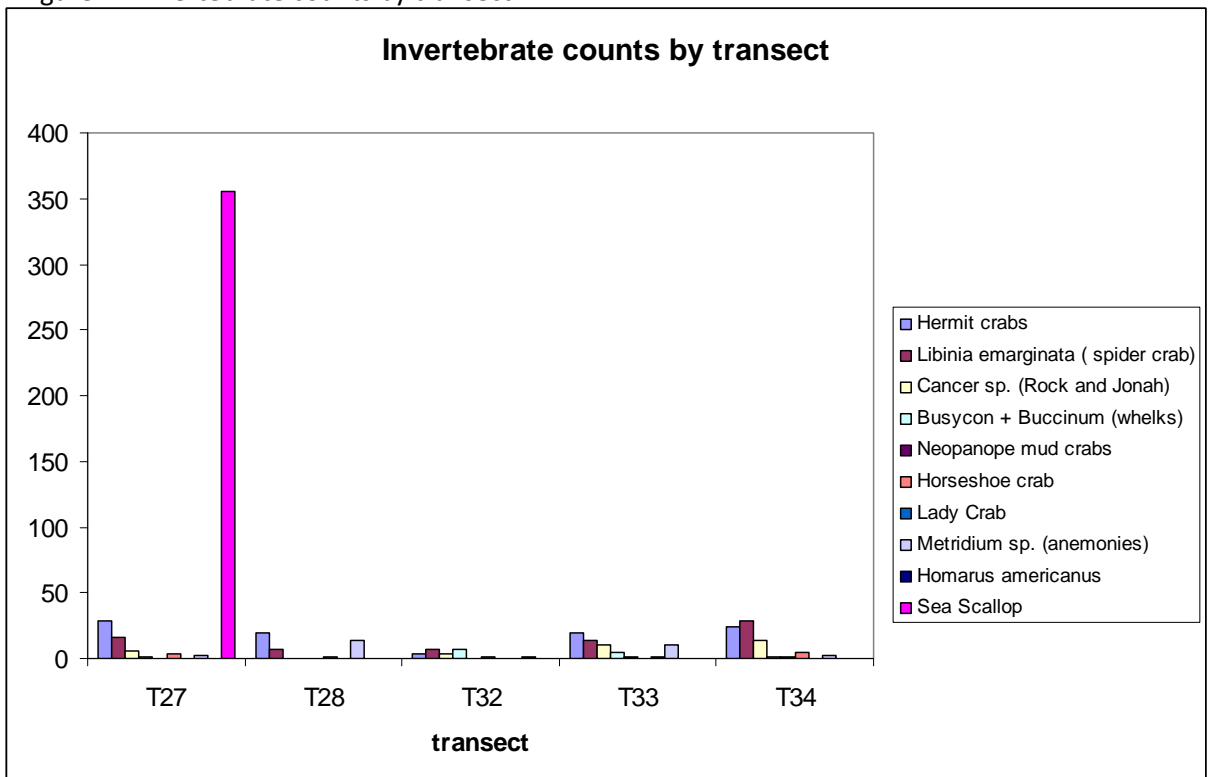


Table 7. Summary of fish counts from all transect locations

Fish (count)	Summary of fish species counts		
	Yarmouth	Harwich	Totals
Black sea bass	487	363	850
Scup	401	10	411
Cunner	47	105	152
Winter flounder	3	4	7
Summer flounder	3	4	7
Tautog	21	5	26
Blue Runner	179	0	179
Lesser amber jacks (juv.)	25	0	25
Butter fish	3	0	3
Spotfin butterfly	5	0	5
Northern sea robin	1	0	1
Totals	1175	491	1666

Table 8. Summary of invertebrate counts from all transect locations

Invertebrates (count)	Summary of invertebrate species counts		
	Yarmouth	Harwich	Totals
<i>Crepidula sp</i>	0	3917	3917
Barnacles	0	1404	1404
Hermit crabs	588	211	799
<i>Libinia emarginata</i> ( spider crab)	1	187	188
<i>Cancer sp.</i> (Rock and Jonah)	0	149	149
<i>Busycon + Buccinum</i> (whelks)	4	41	45
<i>Neopanope sp.</i> (mud crabs)	0	37	37
Bay scallop	0	20	20
Horseshoe crab	0	17	17
Lady Crab	0	15	15
<i>Metridium sp.</i> (anemonies)	1	7	8
<i>Cerianthis</i> (holes)	0	5	5
<i>Botryloides</i>	0	4	4
Quahog	1	3	4
<i>Cliona celata</i> (yellow sponge)	68	9	77
Asian shore crab	0	2	2
White tunicate	0	1	1
Tufted bryozoan	9	0	9
Blue mussel	2	0	2
<i>Homarus americanus</i> (lobster)	1	0	1
Northern Sea Coral (Astrangia)	0	2	2
Sea Scallop	0	358	358
Totals	675	6389	7064

## Appendix A. Yarmouth/Harwich Reef Design, Materials & Monitoring Recommendations

### Artificial Reef Design

To aid in the development of artificial reefs under this proposal, the following criteria should apply to all future reef planning and construction activities:

- *Practicality - Overall design and proposed materials must be easy to acquire or have manufactured and preparation, transportation, and placement costs must be achievable within planned budgetary limits.*
- *Effectiveness - The reef layout and materials used should be designed to provide the users of the reef the best possible chances of receiving the desired benefits of the reef.*
- *Reef configuration - Overall configuration of the materials deployed plays an important role in determining how the reef works as well as its effective use.*
- *Reef profile – Vertical profile (relief) is important in determining the overall species composition of a given reef. For example, low profile reefs are most successful in providing suitable habitat for demersal species such as sea bass, scup, and tautog. Consideration must also be given to navigational restrictions at the proposed site.*
- *Interstitial space (structural complexity) - The quantity and nature of interstitial spaces in reef structures are important in determining the degree and complexity of the biological community developing on and around the reef. Numerous holes, crevices, walls and overhangs in a reef structure allow for a much more diverse community in general than that which would develop on a reef material with less structural complexity.*
- *Total surface area - In most cases, the total biomass that can be supported on an artificial reef will be directly related to the quantity and quality of effective surface area available. This is particularly true of low profile benthic reefs in which the fouling community of sessile marine organisms is important to the subsequent development of the demersal fish community established around the reef materials. The greater the surface area available to these attached and encrusting organisms, the more significant the food source available to other levels of the reef community.*

The Yarmouth Tire Reef was designed to provide a dense concentration of tire units arrayed on the bottom of Nantucket Sound to provide habitat with increased relief and structural complexity for desired finfish and invertebrate species such as black sea bass, scup, and tautog. Efforts to increase the local relative abundance of these species were deemed necessary in light of the deterioration of historically abundant local shipwrecks that served this function and increased demand for fishing access by local residents and seasonal visitors. Subsequent monitoring by DMF and qualitative assessment of recreational/charter/commercial fishing activity in the area of the reef confirmed the success of this project.

Future efforts to supplement the Yarmouth reef and create new reefs off the coast of Harwich will have the same purpose and intent, taking into consideration the experiences and data accumulated in other coastal states that has occurred since creation of the Yarmouth reef. New deployments will create patch reefs of various sizes and shapes, which will provide the desired enhancement of relief and structural complexity. The creation of separate and distinct patch reefs better mimics the natural occurrence of structural relief in Nantucket Sound than deposition in a single large aggregation and will provide greater opportunity for access by multiple users. This approach will also serve to increase the potential for species using these reefs to find shelter and forage areas across a greater portion of the permit area.

## Reef Materials

Two primary categories of materials have been used in the development of artificial reefs in U.S. coastal waters – 1) materials of opportunity and 2) designed/constructed reef units (*Guidelines for Marine Artificial Reef Materials, Second Edition*, ASMFC 2004). Within these primary groupings, there are numerous categories ranging from natural stone to retired naval vessels. All of these material types have structural and economic advantages and disadvantages depending on the proposed site design, intended use, and the level of financial support provided for artificial reef development.

To maximize the opportunities to acquire materials for deployment within permitted reef areas, the permit should be open to both materials of opportunity and engineered structures. Examples of materials that may be considered include concrete culverts, a concrete sewage dry well (honeycomb), natural rock, or manufactured units such as “Reef Balls” or other similar structures. In all cases, the materials should be cost-effective and environmentally safe. Specific considerations include:

- All reef components must be chemically stable, durable and structurally sound. In order to maximize the cost-effectiveness and functionality of the reef, materials should have a planned “life-span” of at least 30 years.
- Materials contaminated by toxic or harmful chemicals such as oils, hydraulic fluids, fuels, or refrigerants are not acceptable.
- All materials/structures must be free of floating debris such as wood, plastics, or trash.
- Materials used for reef construction must have sufficient mass and an appropriate shape to resist movement and burial during adverse sea conditions and minimize the potential for sea bed scouring.
- In addition to physical suitability and resilience, potential reef materials should be evaluated for their potential to provide suitable habitat for the desired fish and invertebrate species.

Additional guidance for the selection of potential reef materials can be found in the *Guidelines for Marine Artificial Reef Materials, Second Edition* (ASMFC 2004).