A GUIDE TO SITE-SELECTION FOR EELGRASS RESTORATION PROJECTS  
IN NARRAGANSETT BAY, RHODE ISLAND

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OVERVIEW:

The intent of this Rhode Island Aqua Fund Project is to address the mandate of the Narragansett Bay Comprehensive Conservation and Management Plan (CCMP) concerning the management of "commercially, recreationally, and ecologically important estuarine-dependent living resources." Due to limitations in funding of the Narragansett Bay Estuary Program, the chapters in the CCMP concerning the management of living marine resources were never completed (identified as "Reserved" in the plan). Nevertheless, the executive summary clearly identifies living resource management as one of the "Highest Priority Actions for Implementation," and specifically recommends species-specific management plans for threatened estuarine-dependent plants and animals.

The first priority of the Aqua Fund project has been to develop a restoration strategy for eelgrass (Zostera marina L.) habitat in Narragansett Bay. Ideally, site selection for restoration activities would be based upon the best possible ecological data such as long-term high-resolution light data, nutrient loading studies, etc. Unfortunately, such studies are costly enough that trial and error restoration attempts could easily prove more cost effective. This restoration plan falls between these two extremes. By considering available ecological data, generating a small amount of new data, researching historic seagrass distribution, and considering current resource use patterns, we have prepared a restoration plan at modest expense that should greatly improve success rate. While even the best conceived habitat restoration plan cannot guarantee success, a thoughtful analysis of potential restoration sites such as this should greatly improve success by identifying promising locations and eliminating consideration of grossly inappropriate ones.

BACKGROUND:

The role of seagrasses in maintaining the physical, chemical, and biological integrity of many coastal ecosystems has been well documented (Thayer et al 1975, Phillips and McRoy 1980, Short and Short 1984, Kenworthy and Haunert 1991). Seagrass beds provide nursery and feeding grounds for numerous species of fish, shellfish, and wildlife, including threatened species and species of economic significance. Furthermore, seagrass beds serve as biological filters by removing dissolved nutrients and suspended sediments from the water column, and preventing resuspension of sedimented material (Short and Short 1984, Kenworthy and Haunert 1991). Recently, there has been a precipitous decline in the number and area of healthy seagrass beds worldwide, which has prompted vigorous research toward better understanding the mechanisms of seagrass loss. Ecological and social benefits that would result from the preservation and restoration of the nation's seagrass communities were well documented by a workshop that brought together both the scientific and resource management communities (Kenworthy and Haunert 1991).

producers through nutrient enrichment, and its resultant shading, is considered the primary culprit. Thus, light limitation is often considered responsible for the decline, with nutrient enrichment being the primary mechanism.

In the late 1800's and early 1900's, eelgrass habitat was prevalent throughout Narragansett Bay. Over the past century, however, eelgrass has retreated from the expansive beds it once occupied. This decline, which is presented in detail later in this document, was typified as a loss of beds from the enclosed basins of the upper bay where light and nutrient conditions were presumably less favorable. As of the 1989 Narragansett Bay Estuary Program habitat mapping survey, eelgrass was generally restricted to the lower reaches of the bay, with only a single vestigial bed remaining in the upper bay (Prudence Island). However, actual seagrass distribution may have been under-represented because marine tradespeople and scientists have testified to knowing of many beds not identified in the Bay Project Report. Aerial mapping completed for this project has also identified sites not documented in the 1989 survey. Some of these corroborate the personal testimony mentioned above, while others were not identified elsewhere.

That eelgrass is more widely spread (albeit thinly spread) than previously believed is both encouraging and discouraging with respect to seagrass restoration. While it is encouraging to find that habitable terrain exists throughout much of the bay, it begs the serious question of why these generally small and scattered beds have not served as seed stock for natural recolonization of more expansive beds. The general restoration edict is that transplanting activities can accelerate otherwise slow dispersal rates or help to overcome critical patch size or patch density requirements. However, it is possible that natural recolonization has not occurred due to persisting habitat unsuitability. At present, only careful selection of restoration sites coupled with equally careful pilot-scale restoration projects can discriminate between these alternatives.

**METHODS OF EVALUATION:**

Selecting a potential planting site can be the single most important step in the entire (restoration) process. It is also the step that is the most difficult to verify objectively because the circumstances contributing to the presence or absence of seagrass at a given site vary tremendously. Proposed planting sites must pass a simple, but exacting test: "If seagrass does not currently exist at the site, what makes you believe it can be successfully established?" (Fredette et al., 1985).

(Fonseca, 1993)

This project presents the unique opportunity to identify potential eelgrass restoration sites based upon valid ecological and societal criteria. Instead of organizing the plan as an evaluation and ranking of arbitrarily selected "potential sites," we have chosen to take a systematic approach in evaluating the various regions of the bay for their anticipated suitability for restoration activities.

Our approach is thus twofold. First, to use the best available information to help in making informed decisions in siting restoration projects. Second, to implement pilot restoration projects at several of the most promising sites to determine if the criteria examined and assumptions made during the selection process are valid for the restoration techniques employed. If demonstration-level restoration projects prove successful, then large-scale projects may be attempted or proposed without undue concern over siting issues or restoration techniques.

The variables we have considered for evaluation are:

1) bathymetric data coupled with light extinction data (generated for this study) to identify large areas of potentially suitable substrate;

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2) exposure of sites to excessively high (or low) wave energy as measured by an index which weights average wind velocity from various compass headings against fetch;  
3) evidence of currently existing beds as identified in the Narragansett Bay Estuary Program habitat maps, aerial surveys completed for this project, and beds identified by the testimony of local marine tradespeople and marine scientists;  
4) evidence of historic beds as identified from U.S. Coast and Geodetic Survey sheets, published accounts, herbarium records, and accounts from interviews with marine tradespeople and "old timers;"  
5) social "current use" considerations.

BATHYMETRY AND LIGHT QUALITY

The light requirements of seagrasses are quite high in comparison with other marine macrophytes, and have been estimated at about 20% of incident irradiation for several species including eelgrass (Kenworthy and Haunert 1991). Since many modern losses of seagrasses have been ascribed to light limitation (Kenworthy and Haunert 1991), good water clarity characterization would be particularly useful when evaluating sites for restoration potential. Unfortunately, long-term, bay-wide light monitoring studies have not been performed. Further, it has been suggested that short-term monitoring is of limited value as a site selection tool, and that even long-term studies are of limited value unless the measurements are made with good time-scale resolution. These assertions are primarily based on the assumption that light measurements are being made to determine suitability of a particular site.

Rather than dismiss all possibility of using water clarity as a site selection tool, we have instead chosen to use it judiciously in combination with bathymetric data to identify large areas where the bay may be shallow enough to support eelgrass growth. In November of 1994, a three-day "synoptic" survey of light extinction coefficients in Narragansett Bay was completed. Approximately 120 stations were visited for measurements of downwelling photosynthetically available radiation (PAR) using a Licor LI-1000 light meter equipped with 2° cosine corrected surface and underwater radiometers. At approximately 30 of these stations, water samples were also collected for chlorophyll a analysis by acetone extraction and fluorescence. November is a time of year with typically low water-column turbidity and chlorophyll concentrations. Our light extinction measurements and chlorophyll a concentrations (appendices I and II) corroborate this expectation with notable regional exceptions. The Sakonnet River was high in chlorophyll a but relatively transparent to PAR, and the upper West Passage was high in chlorophyll a and turbid.

Extinction coefficients were plotted geographically using ASMAP and contoured onto a 100 m by 100 m grid. Appendix II shows the gridded light extinction data for the various regions of the bay (the secchi disc icons represent station locations). Subsequently, the depth of the 20% light level (critical for seagrass vigor) was calculated for each grid box (appendix III). By subtracting this "critical depth" from the actual water depth in that grid box (mean low water as determined from the National Ocean Service Hydrographic Data Base One-Degree Area Inventory), it is possible to identify large areas of the bay where water depths were shallower than the critical depth at the time of the light measurements (appendix IV). For example, a significant portion of Greenwich Bay was shallower than the eelgrass critical depth on the date of the survey; and some of this already supports eelgrass (a three to four-year-old bed off of Chepwiwanoxet Point). Further, while it is important to remember that this represents only a snapshot of light conditions in the bay, the size of the difference between critical depth and actual depth may also be a useful estimate of habitat suitability. For example, eelgrass beds have been identified north of Flint and Black Points in the Sakonnet River where the critical depths were 2 to 4 and 4 to 6 meters deeper than actual depth, respectively.
Used with discretion, we anticipate that this analysis of light conditions in the bay will be a meaningful tool in the process of selecting restoration sites. It must be emphasized, however, that this is a crude tool, especially when considering the dynamic variability of water clarity (in space and over all time scales). Further, the measurement of downwelling PAR extinction coefficients made for this project represent good (if not excellent) light penetration conditions for most of the bay.

ENERGETICS (EXPOSURE INDEX)

It has been suggested by experienced seagrass ecologists Mark Fonseca and Gordon Thayer that wave energy exposure plays a defining role in seagrass bed structure and function (personal communication). As inhabitants of the wave-swept environment, seagrass depth and size distributions may be heavily influenced by wave energy. In order to evaluate potential restoration sites for their suitability relative to wave energetics, an exposure index was recommended. The intent of the index is to compare wave energy exposure of potential restoration sites with the exposure of established sites; thus ensuring that neither excessive wave energy nor stagnant conditions are encountered. This wave exposure index, which was prepared by Applied Science Associates, was generated as follows:

1) The water portion of Narragansett Bay within the study area was sampled with a 100m by 100m grid.

2) At each grid intersection, effective fetch measurements from that point to the nearest shoreline were computed for each of the major 8 compass headings (N, NE, E, SE, S, SW, W, NW).

3) Effective fetch was calculated as the average of 9 cosine weighted fetch measurements made at 11.25° intervals centered about the major axis of the heading of interest. This cosine-corrected average of the 9 fetch measurements was called the effective fetch and accounts for shoreline irregularities.

4) An exposure index value for each grid intersection was calculated by using the eight effective fetch values along with average wind speed and percent occurrence for each of the eight major compass headings using the following equation:

\[
\text{Exposure} = \frac{1}{n} \sum_{i=1}^{n} (\text{velocity} [i] \times \text{percent} [i] \times \text{effective fetch} [i])
\]

Where \( i \) is the \( i \)th major compass heading. The wind data source for this index was the Providence, RI station from the International Station Meteorological Climate Summary. Exposure index results were graphed in ASAMAP geographic information system. The output (appendix V) shows that current eelgrass beds are found (with some exceptions) within an exposure index range of 4 to 10 (m/s * km).

CURRENT EELGRASS DISTRIBUTION

One of the truly critical pieces of information in applying ecological criteria to restoration site selection is an understanding of the environmental requirements of eelgrass. As mentioned above in several locations, synoptic data such as light extinction, critical depth, and wave exposure can all be useful in defining potential restoration sites as long as appropriate values for seagrass habitation are known. While the many of the ecological requirements of eelgrass are known reasonably well (e.g. light requirements), there is no substitute for site-specific examples of these requirements using the same method of evaluation used in site selection. Further, requirements for parameters like wave exposure are not well known. For these to be useful, comparative values are absolutely necessary.

At the onset of this project, the best available source of information on eelgrass distribution in Narragansett Bay was the Habitat Mapping Survey completed for the Narragansett
Bay Estuary Program (1992). While this source appeared reasonably accurate in identifying the major patches of eelgrass in the bay, several more beds that do not show up on the NBP maps were known to exist. Differences in known vs. mapped distributions are probably due to some combination of the following: NBP surveys were not all performed at peak seagrass biomass as is desirable for best resolution; some of the unmapped beds are small and could easily have been overlooked even using superior ortho photographs; some of the known unmapped beds could have established themselves since the Narragansett Bay Estuary Program Habitat Mapping surveys.

In an effort to improve upon mapping of eelgrass distribution, low altitude (600 to 1100 ft.) overflights of all the Narragansett Bay coastline were made. As with the Bay Project overflights, we were unable to coordinate these flights with peak seagrass biomass for logistical reasons. Instead, we chose to have them coincide with the annual senescence of eelgrass meadows. This allowed us to use eelgrass beach wrack as another indicator that beds of submerged aquatic vegetation were indeed eelgrass. Ground truthing for the aerial survey was completed in a variety of ways. Some of the ground truthing was completed by project personnel during the synoptic light survey. Beds that could not be verified at that time were ground truthed with the assistance of volunteers recruited and trained by the staff at Save the Bay. In some instances, Save the Bay ground truthing was limited to verification of the beach wrack. In other cases, on-the-water ground truthing was performed, or personal testimony of scientists, fishermen, and other marine trades people were used as verification for the aerial survey. Appendix VI-d contains the current distribution of eelgrass in Narragansett Bay as identified by the Narragansett Bay Estuary Program Habitat Inventory plus this R. I. Aqua Fund project. The NBP Habitat inventory data are represented as polygons, while the Aqua Fund data are represented by one of two icons depending upon whether ground truthing was performed by Save the Bay volunteers or by URI or RI State scientists (see figure legend for details).

It is interesting to note that, in the process of reconstructing historical eelgrass distributions (detailed below), many more "current" eelgrass beds were identified. This confirms the obvious: that even the most careful remote sensing of habitat type is no substitute for on-the-water observation. Current eelgrass beds identified thorough oral interviews (conducted with the intent of reconstructing historic distributions) are also included in appendix VI.

**RECONSTRUCTION OF HISTORICAL SEAGRASS DISTRIBUTION**

It is sometimes easy to forget that the operative word for the work we are proposing is "restoration." In order to truly perform restoration (as opposed to mitigation) seagrasses must have once grown in the area of consideration. Further, evidence of past seagrass occurrence is a very good indication that a site is (or was) ecologically suited to seagrass growth. While both scientific and non-scientific communities have generally acknowledged that seagrass beds were once widespread throughout Narragansett Bay, to our knowledge no systematic evaluation of historical distributions has been previously attempted. Data from this reconstruction were mapped using ASAMAP GIS software and are displayed in appendix VI.

**Methodology**

**National Ocean Service (U.S. Coast & Geodetic Survey)**

The U.S. Coast & Geodetic Survey (currently encompassed in the National Ocean Service, NOS) performed hydrographic analyses including depth and bottom type descriptions of various locations in Narragansett Bay. All of the original survey sheets and available descriptive reports covering areas of Narragansett Bay from 1832-1948 were analyzed for markings or descriptions of eelgrass locations. Markings that were judged to indicate eelgrass included "eelgrass," "grass" and "grs." that were written in water deeper than the low tide shoreline. A descriptive synopsis of NOS survey references to eelgrass is provided in appendix VII.

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All areas of survey sheets that included eelgrass markings were photocopied. Using these copies, polygons were drawn onto an ASAMAP GIS data layer to represent eelgrass locations which corresponded to the position and size of the word "eelgrass," "grass" or "grs." that was written on the survey sheet. Some interpolation was made when "eelgrass," "grass" or "grs." was written multiple times in close proximity. Each polygon was overlaid with an icon of a down-facing black triangle to represent the source of the data as National Ocean Service survey sheets. The labels for each plotted location begin with a "C" for chart, followed by the survey sheet number, a letter referring to a text description of a site and the date of the survey.

Archival Research

The following archives were searched for records relating to eelgrass distributions in Narragansett Bay: R. I. State House Library (Annual Reports of the Commissioners of Inland Fisheries, Shell Fisheries and Department of Agriculture and Conservation), RI State Archives, RI Historical Society (including the graphics department), Woods Hole Oceanographic Institute Archives, Providence Athenaeum, and National Archives (Department of Agriculture and U.S. Fish & Wildlife record groups.)

Herbarium Records

Requests were made at eleven herbariums for preserved specimens of eelgrass or widgeon grass (*Ruppia maritima*) collected from Narragansett Bay. Most of the herbariums in New England were contacted, in addition to major herbariums such as the United States Herbarium (Smithsonian), the Philadelphia Academy of Natural Sciences Herbarium and the New York Botanical Garden Herbarium. A descriptive synopsis of herbarium specimens of *Zostera marina* from Narragansett Bay is provided in appendix VIII.

Locations from which herbarium samples were collected are identified on ASAMAP GIS data layers using an icon of a solid black square. The labels for each plotted location begin with an "H" for herbarium, followed by a one or two-letter code for the general location, and the year of collection.

Literature References

A search was conducted in the Biological Abstracts for studies performed on eelgrass or in Narragansett Bay from 1910-1950. The indices for all issues of Rhodora were also checked for eelgrass references. Cross-references from various reports regarding historical distributions of eelgrass were also investigated. Cottam's reports in Plant Disease Reporter on the impact of the wasting disease in the 1930's were also examined for references to Narragansett Bay. A descriptive synopsis of literature references to eelgrass in Narragansett Bay is provided in appendix IX.

Geographic locations for literature citations are identified on ASAMAP GIS data layers using an icon of an upright black triangle. The labels for each plotted location begin with an "L" for literature, followed by a two-letter code for the author, a one-letter code for the general location, and the year of collection.

Oral Histories

To obtain subjects to interview regarding eelgrass locations, nearly all of the fish and shellfish wholesale stores in Rhode Island were contacted and asked for names of people who might be knowledgeable about eelgrass locations. The RI Shell Fisherman's Association and the RI Divers Association were also contacted. Interviews were conducted with approximately thirty people who knew either past or present eelgrass locations. Face-to-face interviews were held.
with twelve of these people who were either over the age of sixty and knew many historical locations or who were younger but very knowledgeable about more recent locations.

During the face-to-face interviews, which lasted from 20 minutes to 2 hours, the subjects were first shown color pictures of eelgrass and were told the differences between Spartina and Zostera to ensure that the person was referring to eelgrass and not cord grass or marsh hay. The subjects were also asked to describe the organisms they saw in the grass beds and the type of activities that people were involved with inside the grass beds. Thus, if the response was that the subject scalloped in the grass beds or if the subject referred to the grass beds as being on the beach, a distinction could be made to whether the subject understood the difference between subtidal eelgrass and intertidal cord grass.

The subjects were asked to describe the locations, dates of existence, depths and possible causes for decline of eelgrass beds. The subjects were asked to draw the locations of the eelgrass beds on a NOAA chart of Narragansett Bay.

All of the face-to-face interviews were taped and transcribed so that later analysis could be performed regarding interpretation of the reliability of the information. Phone interviews were not taped although notes were taken.

Each location that a person described was assigned a reliability score on a scale of 1-3 with 1 being the least reliable and 3 being the most reliable. Reliability was based on the apparent ability of the person to distinguish eelgrass from Spartina and on the vividness of their memory.

The data regarding eelgrass locations and dates from all of the interviews were organized by geographical location and time and were grouped into coarse time intervals (see appendix VI).

All of the data that had dates and locations well described were plotted using ASAMAP. If the eelgrass bed was drawn by a subject on a map, an equivalent polygon was drawn using ASAMAP. If the eelgrass bed was only described verbally or if the eelgrass bed was very small, it was represented by an circle icon. A circle icon was also placed on top of each polygon to designate the data source as being the oral interviews. All of the plotted oral history information have labels that begin with "P" for "person/oral interviews," followed by a reliability factor between 1-3, a two letter code corresponding to the name of the informant and the dates of the eelgrass bed.

Historic Distributions

Providence River, Seekonk River, Palmer River and Hundred Acre Cove

1840-1919

Based on the U.S. Coast & Geodetic Survey (USCGS) survey sheet number 878, in 1865 eelgrass grew at various locations in the Providence River from the mouth of the Seekonk River to north of Gaspee Point at depths from 1-4 feet at mean low tide.

In 1913 the USCGS survey sheet number 3565 has "grass" written from Nayatt Point to the Barrington Beach area and also along the coast south of Conimicut Point.

Russell Wallis (77 years old) reports that his father and grandfather and many of the residents along the shores of the Palmer River used to harvest eelgrass from the Palmer River in the 1910's to use as insulation. He also remembers commercial harvesting of the eelgrass for fertilizer.

The beds described by Wallis on the Palmer River were likely present as far back as the mid 1800's. In a literary reference, eelgrass beds were described to have "dotted the surface as far as we could see" in the region of the Warren Bridges by author Henry Cady (under the pen name Wallace Stanley, 1891, p.28). The story was reportedly based upon Cady's true boyhood adventures on the Palmer River (Peck, 1947).

1920-1939
The oral interview data indicate that the 1938 hurricane significantly damaged eelgrass locations in the Providence River region. Robert Rayhill (73 year old shellfisherman) recalls scalloping in eelgrass beds west and northwest of Greene Island (midwestern portion of Providence River) and north of Conimicut Point in 1935. He also remembers eelgrass living east of Nayatt Point in the Barrington Beach area sometime between 1935-1951. Eddie Guay (66 year old shellfisherman) remembers eelgrass being in the Providence River. Arthur Ganz (Fish & Wildlife) was told by old-timers that eelgrass was in the Providence River from the 1920's until the 1938 hurricane.

Wallis also was told by old-timers that the Providence and Seekonk Rivers used to have eelgrass. Guay (low reliability) remembers eelgrass in the Providence River as far north as the Mobile docks until the 1938 hurricane. Wallace remembers eelgrass in the Warren River until 1940. According to Wallis, there was eelgrass in the Palmer River in the late 1930's and less in the 1940's. Rayhill remembers eelgrass at Barrington Beach east of Nayatt Point sometime between the late 1930's to 1950.

1940-1959
Eddie Guay remembers eelgrass living around Starved Goat Island until the land was filled in to create the current Field's Point shoreline. He also recalls eelgrass living around Greene Island and in Occupessatuexet Cove and in Bullock Cove (low reliability).

Russell Wallis remembers there being small amounts of eelgrass in the Barrington River and in Hundred Acre Cove which disappeared around 1955.

Russell Wallis reports that the Palmer River was filled with eelgrass in the 1930's and less in the 1940's while Bill Noland (70 year old scalloper/shellfisherman) recalls eelgrass in the Palmer River before 1945 which he thinks began to decrease in 1965-70 until it was completely gone in 1980.

1960-1995

Mount Hope Bay
The Kickamuit River had eelgrass along its western side in the 1930's according to Rayhill. Noland recalls seeing eelgrass at Bristol Narrows at the mouth of the Kickamuit River and along Chase Cove in the southeastern portion of the river in 1940-63.

Noland remembers the Cole River having eelgrass in the 1930s. In his 1929 study, Setchell refers to eelgrass growing around the most southern road bridge of the Lee River in 1921-23 (Setchell, 1929).

Bristol
In 1901 a brown algae is noted to appear on eelgrass in Bristol Harbor. (Schuh, 1901) A USCGS study (3571) in 1913 indicated eelgrass in the northern portions of Bristol Harbor. Along the shore of Colt's State Farm/Park, Setchell (1929) found eelgrass in 1921 (verified by 1921 herbarium sample, United States Herbarium, Smithsonian Institute). Noland remembers seeing eelgrass in upper Bristol Harbor from 1955-65 and in Walker Cove on the southeast side of Bristol Harbor from 1945-65. Shirley Johnson (quauger) reports having seen eelgrass on the west side of Bristol Harbor since 1985 and near Colt State Park in 1980.

Prudence, Patience, and Hog Islands
Patience Island and Western Prudence Island

The cove on the west side of Providence Point had eelgrass in 1865 according to USCGS survey 880. Eelgrass was also indicated on a 1913 USGS survey (USCGS 3572) between Patience and Prudence Islands. Noland remembers eelgrass in Coggeshall and Sheep Pen Coves in the period 1945-60. Ganz thinks that eelgrass has been between Prudence and Patience Islands up through the early 1970's at least. Luther Blount (property owner-Prudence Is.) remembers eelgrass at Jenny's Creek in the midwestern part of Prudence Island.

Eastern Prudence Island

Wallis remembers eelgrass in Potter Cove in 1939-41. George Drew (shellfisherman), Don Wilcox (78 year old shellfisherman/boat builder), and Rayhill all recall eelgrass in Potter Cove prior to 1945. Ganz thinks that there was eelgrass in the northern part of Potter Cove until the early 1970's at least. Rayhill remembers eelgrass at Mt. Tom before 1950 and along the mid west shore in 1939 to before 1949. David Esau (quahauger) remembers eelgrass on the mid western portion of Prudence Island north of Homestead until 1970.

Johnson and John Langella (diver, biology teacher) both remember seeing eelgrass on the south side of Prudence in the 1990's.

Hog Island

USCGS survey 3571 in 1913 indicated eelgrass on the northern and southwestern portions of Hog Island. According to Ganz, the west and the southeast corners of Hog Island used to have eelgrass in the late 1960's to the early 1970's. Noland also remembers eelgrass in the southeast cove of Hog Island in 1965. Johnson recalls seeing eelgrass around Hog Island in the 1990's.

Greenwich Bay to Allen Harbor

Greenwich Bay

Based on the USCGS survey 3572 performed in 1913, there was eelgrass in many parts of Greenwich Bay; the southeastern portion of Apponaug Cove, west of Cedar Tree Pt, south of Oakland Beach, north and northeast of Chepewonoxet Pt., and east of Sally Pt. Since the survey did not include sections of near-shore regions, there may have been other eelgrass locations existing at the same time. Wilcox was told by his father that the entire coastline from Apponaug Cove to Warwick Neck was filled with eelgrass before 1920.

"Reports and hurried inspection" of the shallow portions of Greenwich Bay in June 1936 by the U.S. Biological Survey yielded no eelgrass (cited in Renn 1937). Rayhill remembers eelgrass living in almost every part of Greenwich Bay prior to the 1938 hurricane up to depths of 15 feet at mean low tide. In the mid 1940's, Rayhill recalls scalloping in an eelgrass bed north of Chepewonoxet Point and Agin recalls two eelgrass beds between Sally and Sandy Points which existed between 1945-65. Ganz remembers a patch of eelgrass from the mouth of Brushneck and Buttonwoods Coves to the mouth of Warwick Cove in the 1960's. North of Chepewonoxet is reported to have had eelgrass from 1975-90s (Bob Fitzpatrick [swimmer, snorkeler]), before 1987 (Langella) and in 1992 (Mark Lapteau [underwater photographer]). Langella also reports to have seen eelgrass west of Sally Point in the 1990s.

Potowomut River

Based on the USCGS survey conducted in 1913, there was eelgrass on both sides and at the mouth of the Potowomut River. Middleton Gammell (property owner/recreational user of Greene R.) was told that there was eelgrass in the river from prior to 1900 to 1940. Wilcox was told by his father that the Potowomut River had eelgrass before 1935. Ganz, Agin and Gammell recall eelgrass being in the Potowomut River in the 1960's until as late as 1975. Langella remembers eelgrass in the river from the late 1980's to 1994.
Between Potowomut River and Allen Harbor
USCGS survey 3572 indicates that there was eelgrass south of Tibbet's Creek between the Potowomut River and Allen Harbor in 1913. Rayhill recalls eelgrass in the same location prior to 1951 while Lapteau and Langella recall eelgrass growing there in 1970-90.

Allen Harbor
USCGS survey 3572 shows eelgrass growing at the mouth of Allen Harbor in 1913. Wilcox was told that there was eelgrass in the harbor prior to 1935. Langella remembers seeing eelgrass in the western portions of the harbor in 1994.

Wickford Harbor and Quonset Point
USCGS survey 992 shows eelgrass growing on either side of Quonset Point. in 1868 (the shoreline was significantly different then.)

USCGS survey 992 indicated eelgrass in the northern portion of Fishing Cove in the northwest portion of Wickford Harbor and south of Wickford Harbor along Poplar Point. in 1868. A 1936 study by the U.S. Biological Survey based on "reports and hurried inspection" yielded no eelgrass in Wickford, "a matter of great concern since the beds had heretofore furnished excellent protection to young lobsters." (Renn 1937) Wilcox reports that there has been eelgrass in Wickford Cove by the yacht club since 1935 and that there was eelgrass in the northern portion of Fishing Cove and between Vile's Creek and Sauga Point. between 1937-45. Rayhill reports that there was eelgrass from between Vile's Creek and Sauga Point. in 1950. Ganz recalls seeing eelgrass in Fishing Cove in 1965-75. Four people (Ganz, Noland, Karlsson, Wilcox) remember seeing eelgrass in Wickford Cove by the yacht club in the general time of 1970-85.

West Passage
North Kingston and Narragansett
A 1868 survey by the USCGS (992) indicates that eelgrass was living outside of Bissel Cove between Wild Goose Pt. and south of Rome Pt. and also north and east of Plum Point. Wilcox was told by his father that Bissel Cove had eelgrass before 1920. Jeffries remembers seeing eelgrass/Spartina mixture around Lone Tree Pt and the cove south of Cold Spring Rock and in Bissel Cove in the early-mid 1970's.

Pratt recalls seeing eelgrass at Baby Beach of the URI Bay Campus and on Bonnet Shore at the end of John Gardner Rd. since 1992 while John Plikus (spearfisherman) remembers seeing it south of Bonnet Point. since 1985. Langella also remembers seeing eelgrass on both sides of Bonnet Point. until the early 1980's.

Western Shore of Jamestown
The USCGS survey 992 performed in 1868 indicates that eelgrass was living on the northwestern part of Conanicut Island and also from south of Hull Ledge to the current location of the Jamestown Bridge on Conanicut Island. A 1912 survey by the USCGS (3403) showed eelgrass living on the southern side of Dutch Harbor. The east side of Dutch Island had eelgrass before 1935 according to Wilcox. Pratt remembers eelgrass growing on the west side of Beaver Neck south of Austin Hollow since 1960.

Langella recalls seeing eelgrass on the north and northwest parts of Conanicut Island in 1990. Both David Swain (diver) and Charles Walpole (diver) report seeing eelgrass in Dutch Harbor in the 1990's.

East Passage
Eastern Shore of Jamestown
Two herbarium samples from 1879 were collected in Jamestown with no detailed location descriptions (Brown University Herbarium). Langella recalls various patches of eelgrass on the east side of Conanicut Island in the 1990's. Potter Cove is said to have had eelgrass since 1980 (Lapteau) and since the 1970's, but not much lately (Langella). An herbarium sample was taken from East Ferry in 1969 (Champlin, Grey Herbarium, Harvard University). Lapteau recalls seeing eelgrass on the south side of the Newport Bridge in Jamestown from 1985-94. Wilcox recalls seeing eelgrass at the Dumpings since 1965-70 and Swain, Carney and Warnock recall it there in the 1990's.

Many people remember seeing eelgrass at Fort Wetherhill at various times; since the late 1960's (Langella), since the 1970's (Swain), since the early 1980's (Krueger and Mather) and in the 1990's (Walpole, Carney and Plikus). Mackerel Cove is also well remembered by several people; since 1975 (Langella) and in the 1990's (Walpole and Plikus). Langella reports having seen eelgrass in Hull Cove on the southeast side of Beaver Neck from 1975-90's although he thinks there hasn't been as much lately.

Newport
An herbarium sample from 1848 is labeled as having been taken from Newport (Brown University Herbarium). East of Coaster's Harbor Island had eelgrass markings on the 1880 USCGS survey sheet 1468. George Mendosa (72 year old fisherman) also remembers eelgrass living near King's Park off Wellington Ave from 1925 until 1975-80. Ganz remembers eelgrass growing in the same location in 1970-75.

On the outer coast of Newport there have been numerous reports of eelgrass. In 1921-23 Setchell performed phenomenological observations on a patch of eelgrass in a small cove between Brenton Point and Price's Neck and took four herbarium samples from this location (Setchell 1929). Mendosa recalls seeing eelgrass around Price's Neck since 1925 although in some years he remembers "little decreases." At Castle Hill inside of Butter Ball Rock. Langella remembers patches of eelgrass from the 1970's to 1990. The Green Bridge area west of Price's Neck had eelgrass in 1975 according to Silvia and in the 1990's according to Lapteau and Swain. Ganz remembers eelgrass at Cherry Neck since the early 1970's. Between Brenton Reef and Price Neck there has been eelgrass since 1985 according to Plikus. Eelgrass is also reported between Price Neck and Seal Rock recently by Langella.

Sakonnet River Area

The Cove (Portsmouth)
In 1917, the descriptive report accompanying USCGS survey 3995-6 indicated eelgrass growing in the Cove in Portsmouth. A 1923 herbarium sample was taken from the Hummocks at the Cove (Setchell, United States Herbarium, Smithsonian Institute). Ganz remembers seeing eelgrass around Spectacle Island in the Cove and in the western portions of the Cove from 1970-90s.

Nannaquaket Pond
In 1917, the descriptive report accompanying USCGS 3995-6 indicated eelgrass growing in Nannaquaket Pond. Mendosa recalls eelgrass being in the pond consistently during the 1930's. Nannaquaket Pond was said to have eelgrass in 1945 (Wallis), 1955 to after 1960 (Noland), 1950-60s (Ganz).

Sakonnet River
Rayhill recalls eelgrass living in 1951 from Portsmouth Park to Island Park south of the Cove, the areas north and south of McCurry Point, around Black Point and in the cove south of Fogland Point. Mather remembers seeing eelgrass at Island Park south of the Cove in the 1980s.
Ganz remembers seeing eelgrass at the Sapowet Marsh area after 1970 and at the mouth of the Nonquit River in the early 1970s.

**HIGH PRIORITY AREAS FOR EELGRASS RESTORATION ACTIVITIES:**

On April 12, 1995, we convened a working group to review the above criteria and identify appropriate sites for pilot restoration efforts. Participating in the evaluation and selection process were representatives from universities, state and federal governments, and interest groups. The information described in this report had been entered into ASAMAP GIS software and was used as an evaluation tool for the meeting. Benefiting from the combined expertise and local knowledge of the participants, an interactive interrogation for suitable restoration sites ensued. Social considerations such as current and anticipated activities in each region were considered at this time. Also considered were information on sediment grain size (from McMaster and Clarke, 1956), and the potential impacts of nutrient enrichment (nutrient susceptibility) on enclosed basins around the Bay. The latter is currently under study by the URI Coastal Resources Center (A. Desbonet and V. Lee, personal communication).

At the close of the working session, 22 sites were identified as high-priority restoration locations from locations throughout Narragansett Bay including Mount Hope Bay and the Sakonnet River (appendix X). The US Army Corps of Engineers and the RI Coastal Resources Management Council subsequently granted permits to the University of Rhode Island and to the National Marine Fisheries Service to perform specified restoration activities at any of these sites. As part of the URI contract with RI Aqua Fund, six pilot-level restoration sites were to receive shoot transplants. Three sites (Hope Island, Potowomut River, and Greene Point) were identified for year one restoration activities.
REFERENCES:


Stanley, W.P. 1891. Our Week Afloat; or, how we explored the Pequonnset River. Chicago: Belford-Clarke Co.


APPENDICES

APPENDIX I:
Chlorophyll $a$ vs extinction coefficients for stations throughout Narragansett Bay.

APPENDIX II:
Vertical Light Extinction Coefficients ($k$) for Narragansett Bay

APPENDIX III:
Estimated Critical Depth for Eelgrass in Narragansett Bay

APPENDIX IV
Difference Between Eelgrass Critical Depth and Actual Depth in Narragansett Bay

APPENDIX V:
Wave Exposure Index Values for Narragansett Bay

APPENDIX VI:
Historic and Present Distributions of Eelgrass in Narragansett Bay
   a. 1840-1899
   b. 1900-1939
   c. 1940-1979
   d. 1980-1994
   e. 1840-1994

APPENDIX VII:
Descriptions of Eelgrass Locations from National Ocean Service Survey Sheets

APPENDIX VIII:
Herbarium Records of Eelgrass Distribution

APPENDIX IX:
Eelgrass Locations in Literature References

APPENDIX X

PROPOSED HIGH-PRIORITY EELGRASS RESTORATION SITES