Casco Bay Fringing Marsh Mapping and Survey Project

Fringing marshes are small salt marshes that form along estuary channels, protected coves, and other areas shielded from heavy wave action. Unlike the better known barrier or finger salt marshes, fringing marshes are small – often only a few meters long and a meter or two wide – and, because of these characteristics, have not been documented in resource or ecosystem inventories as have larger salt marshes. With an increasing appreciation of the ecological significance of these small ecosystems, there is increasing interest in documenting their existence and, where appropriate, improving efforts for their protection.

In the spring and summer of 2007 the Environmental Protection Agency (Region 1 office in Boston) and the Casco Bay Estuarine Partnership commissioned the Wells National Estuarine Research Reserve (WNERR) to map fringing marsh along the mainland coast of Casco Bay, Maine. Early (spring) work was to involve the use of aerial imagery to identify fringing marshes along the mainland coast. Later in the summer, after vegetation had matured, teams would perform field surveys at randomly-selected sample points to obtain information not available from aerial photography.

The goals of the project were to produce GIS-compatible files of the location and areal extent of the fringing marshes along the mainland coast. Field surveys were to provide estimates of the size of marshes as measured using hand-held GPS units. Those marshes surveyed were subjected to a 'rapid assessment' protocol that provided quick estimates of characteristics significant in evaluating marsh health and degradation causes. Finally, as part of the GPS measurements of marsh area, the perimeters of a subsample of marshes were to be measured at an elevation of forty centimeters (40 cm) above the existing marsh perimeter. This would provide an estimate of the potential marsh adaptation to a predicted 40 cm rise in sea level over the remainder of this century.

Data, Methods, and Products

Study Area

The study area consisted of the mainland coast between Cape Elizabeth in the southwest and Small Point in the northeast. Islands, in general, were not included in the study coastline, although some islands lying close to or connected to the mainland were evaluated and, where fringing marsh was found, delineated. The study area was divided into two regions: the western region, comprised of approximately 250 km of coastline between Cape Elizabeth and Harpswell; and the eastern region, comprised of approximately 400 km of coastline between Harpswell and Small Point. Figure 1 shows the study area in Casco Bay and the two study areas.

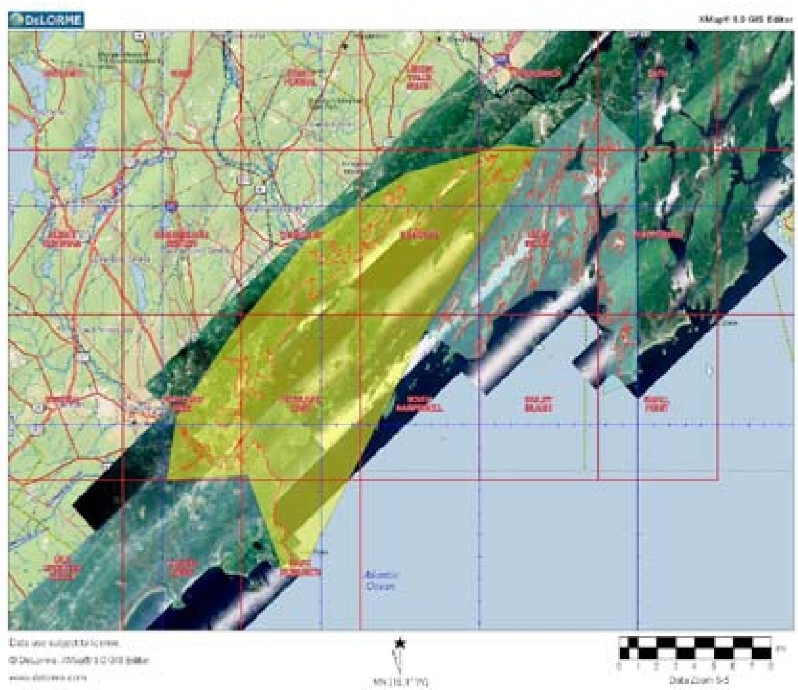

Figure 1: Study area for fringing marsh project

The coastline shown was evaluated visually using the DeLorme XMap GIS software and the accompanying Topobird imagery. Areas believed to be fringing marshes were delineated by drawing a polygon enclosing the identified marsh. Field surveys were later conducted at randomly selected points within the two regions of the study area. See the *'Methods'* section for more details.

Image Data

Digital Imagery Selection Considerations

Data for the GIS delineation of fringing marshes in Casco Bay was primarily image data – often referred to as raster data in GIS use. A number of sometimes-competing criteria that led to the selection of the data used are briefly described below.

Pixel Considerations - Resolution. Imagery is usually a trade-off between resolution (many pixels in the same real ground area mean better resolution but larger data files), color (more words per pixel and larger words per pixel mean more accurate color, or other bands, such as the near infrared, NIR, but larger data files), the number of flights (more flights with less ground area covered per image taken leads to better resolution with greater expense both during and after the image capture), and other potential factors. For our purposes, color imagery was required with a minimum of six-or-twelve-inch ground resolution. Much less than a one-foot resolution made identification of the marsh area impossible. Individual stalks were 'invisible' (a stalk of cordgrass is only a fraction of an inch wide and even a leaf is less than an inch across), but the overall color and some texture were visible, and outlines between vegetation types could sometimes be discerned in the six-or-twelve-inch-imagery. The fringing marsh project was not intended to produce new imagery, so only existing imagery was considered.

Season and Time. Another consideration especially important for this type of work was the season in which the imagery was taken. Marshes may be growing in May, but there is little above-ground foliage (and certainly not a lot visible from an airplane) until later in the summer – late June or July – at which time there are even sometimes sufficient differences in image signatures to determine species boundaries. Unfortunately, many aerial imagery projects attempt to limit the visual obstruction that occurs from trees and other foliage by intentionally flying after the snow cover has melted but prior to the emergence of leaves – 'leaf-out'. This means that much of the imagery produced for other purposes (for example, municipality planning, facility planning, and other common uses of such imagery) is not well suited to delineating fringing marsh (or other salt marsh, for that matter). This is particularly important in determining marsh from other vegetation types as the height and texture differences become more pronounced as the vegetation grows (particularly where marsh abuts lawn in developed areas or algae-covered rock).

Imagery taken prior to leaf-out served as a second source to verify the boundaries of marsh peat (especially, for example, where a visible salt marsh disappeared beneath deciduous tree cover along a coast), but much of the available 'standard imagery' could not be used for primary marsh identification as the differences between senescent marsh and other types of vegetation was not detectable. Even during the proper season – with reasonably mature growth – the height of the tide was a significant factor in the ability to see and delineate marshes as low marsh is often submerged at high tide. The ideal time was low tide, when the marsh would be most exposed, its lowest edge visible above the low water. Although dead-low-tide was not necessary, high tide imagery could conceal some low marsh areas beneath the water and was not acceptable.

Georeferencing and Image Processing. Georeferenced and rectified imagery was necessary because the goal of the identification was to locate likely fringing marshes for future use. Distortion in the orthorectification process (correcting for camera perspective distortion) would make identification and location difficult.

'Public' Sources of Data
The state office of GIS was the primary provider of appropriate imagery candidates. The state GIS web site (http://apollo.ogis.state.me.us/) provided access to a number of image sets covering a majority of the coast. Citipix or Ortho_HF imagery was six-inch-resolution imagery available for all the western study area; only twelve-inch resolution imagery (Ortho_1F) was available for some locations in the far eastern study area (primarily near Phippsburg). This imagery (the Citipix or Ortho_HF and the Ortho_1F, respectively) were full-color, orthorectified, georeferenced images of Maine land and coastline, but they were taken in early spring, prior to leaf-out, and didn't allow identification of marsh vegetation. While some marsh features (particularly areas of peat) were visible in this imagery, its use for this project was limited to a 'backup' capacity: it might be used to help determine whether or not a questionable area (in another photo) was or was not fringing marsh, but could not be used for primary identification.

DMR Eelgrass Photos
The Maine Department of Marine Resources (DMR) possessed another set of imagery that had good resolution, were taken during the summer (with the intended use of identifying eelgrass beds in coastal waters, so vegetation was present), and were partially orthorectified and georeferenced. These images were missing sections of the coastline (they were intended for eelgrass bed identification), and not all images were georeferenced. They were used as another 'backup' to the primary imagery, to check a questionable location and for another, possibly better, view, as well as to ensure that a 'marsh' was not a bed of near-shore eelgrass.

DeLorme TopoBird Imagery
Through a series of inquiries and strings of contacts, a set of imagery was found at the DeLorme Map Company of Yarmouth, Maine, that had the characteristics desired. The resolution was approximately twelve inches and the clarity was excellent, owing partly to the equipment used to obtain the images. The flights had all been made during near low tide during the summer so that there was a full cover of marsh vegetation. DeLorme graciously loaned us the imagery and copies of XMap (the GIS and mapping software they produce and in whose format the imagery was saved) for use on the project. This served as our primary image source for image-based identification of fringing marshes. Figures 2 and 3 show the image sources for a common location in Falmouth for comparison.

Figure 2: DeLorme Topobird Imagery of Falmouth coastline

Figure 3: Citipix (or Ortho_HF) imagery of Falmouth coastline

Other Data

The state's GIS website served as the source of a number of non-image data sets (vector data in GIS parlance) used during our identification. We used the Coastal Bluff Hazards layer from the Maine Department of Conservation and the Maine Geological Survey as a guide to the coastline of Casco Bay, following most of the same contours when searching for and delineating marshes. This layer also provided a field containing a classification of the shoreline throughout most of the study area – one classification being salt marsh (or other vegetated shore). We utilized this as a guide and found that our identification didn't always agree (different years, different identification means, and different classifications, among the differences between the two), but the areas identified in this layer as marshes were paid particular attention in the imagery in an effort to ensure that all potential fringing marshes were inspected and, where appropriate, identified.

The Maine GIS site's Eelgrass Beds layer was also used to help ensure that what appeared to be a salt marsh at higher tide was not an eelgrass bed at lower tide.

Methods and Results

Image-Based Delineation

The image-based identification primarily involved following the coastline in the imagery (the DeLorme Topobird imagery being the primary source used for this purpose) at a scale that was appropriate for picking out sections that might be fringing marsh. Fringing marsh was primarily identified by its color, texture, and location. Once a marsh was identified, a polygon (a shape created by hand in the XMap program whose boundaries approximately followed the marsh boundaries and which could be displayed in the GIS program) was drawn around it and was saved to a database of identified marshes that would eventually become part of the shapefile deliverable.

As the mapping effort progressed, fields were added to the marsh database to indicate aspects of the identification process. Initially, we believed that we had the capability to differentiate between patches of different dominant vegetation from the imagery. In preparation for this, a single-character field was added to indicate high marsh (H), low marsh (L), mixed marsh (M), or invasive (I). Although there were some locations at which our optimism was valid, a vast majority of the marshes identified were simply identified as mixed fringing marsh because no real boundaries between vegetation types were detectable with any confidence.

Similarly, the difficulty of identifying vegetation as fringing marsh was greater than we initially expected. Overhanging foliage from trees along the shore was a major obstacle to determining the underlying surface vegetation, but there were other surprises. Lawns in some developed areas appeared surprisingly marsh-like at even a six-inch resolution, and, at times (often dependent on tide, lighting, and photograph angle), algae-covered rocks or silt appeared nearly indistinguishable from salt marsh. A field was added to attempt to capture the operator's confidence in the identification. This involved a simple number from 1 through 4 indicating decreasing confidence of a marsh identification (1 being most confident, 4 being least).

A final field added late in the process was a description of the coast type. This was a 'catch-all', single-character field that was intended to indicate the factor that the operator thought most interfered with his or her ability to identify the surface vegetation as fringing marsh or something else. The choices used were 'F' (foliage or forested, primarily used where overhanging foliage prevented a good view of a the coast beneath), 'M' (silt, mud, algae-covered rocks, or other substrate-based cover that appeared to be potential marsh), and 'U' (for developed lawns or other domesticated vegetation that made identification difficult).

The process involved slowly searching along the XMap imagery until a likely marsh was found. This was sometimes done individually and, at other times, with two people (the images were shared with a networked drive and each person used a copy of XMap). When a potential marsh was identified, a polygon was drawn around it using XMap – assuming it was classified as a marsh. As mentioned earlier, determining whether or not a potential marsh should be classified a marsh was sometimes difficult. To help, portions of the 'backup' image sets were often loaded either into XMap or ArcMap. While these were often not ideal (being taken during the wrong season, in the case of the Ortho_HF and Ortho_1F imagery, for example), they often provided clues that helped make a better decision and changing between two or more image sets often helped the process.

One example of such challenges in this process is shown in Figure 4 (top) where (in the Topobird imagery) shade covers one side of a peninsula, preventing identification of the coast covering, while the other side of the peninsula contains areas covered in some manner of vegetated coast, but not immediately identifiable as fringing marsh. The Maine Ortho_1F imagery (taken in April) showed what appeared to be marsh peat – with a texture and elevation differences from surrounding areas – that convinced the operator to delineate marsh shown in Figure 4 (bottom).

The end result of the image identification of marshes in Casco Bay was a combined total (marshes from both the east and west regions of the study area) of 1159 marsh candidates, ranging in size from approximately ten square meters to over a hectare (10,000 square meters). Determination of the area of image-identified marshes was not one of the initial project goals – only the linear extent was to be determined from the imagery. However, the boundaries of marshes identified using the aerial imagery were delineated as accurately as possible with the XMap polygons, and the software calculated the area of those polygons, so that area was available immediately. Figure 5 shows the distribution of fringing marsh areas (on the vertical axis) based on the aerial identification, along with the percent ranking by area (along the horizontal axis) of the marshes.

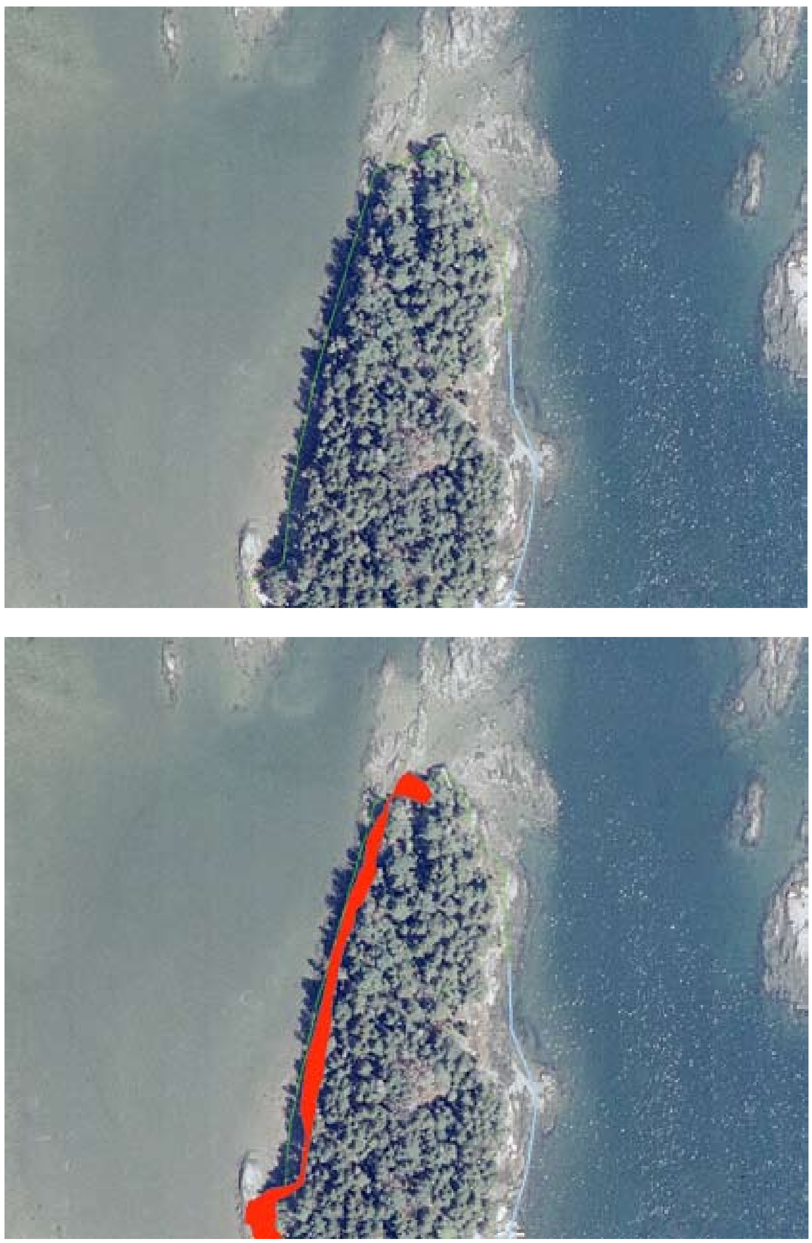

Figure 4: Difficult identification area and the marsh eventually identified using multiple resources

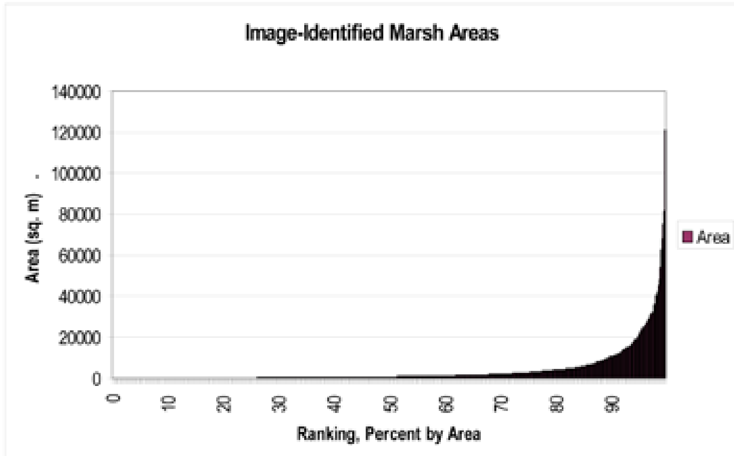

Figure 5: Image-based marsh areas in square meters and ranking in percent.

Boat-Based Surveys

While delineating marshes (especially after discovering just how difficult identification could be), discussions turned towards potential means of estimating the accuracy of the image-based identification process. There was no way to return to the year during which the imagery was taken and map the marshes existing then. However, there was the possibility of finding the marshes existing in the summer of 2007 and using them as an estimate. There would obviously be differences as marshes appear, disappear, grow, and shrink over four years, but an estimate of the location and size of existing marshes would provide the best available metric for the image-based identification process.

As an extension to the original project proposal, a boat-based survey of portions of the coast was agreed upon to obtain estimates of the existing marshes. The boat survey consisted of a boat traveling slowly parallel to the shore while observers used binoculars to search for marshes along the shore. When a marsh was sited, a hand-held GPS (Global Positioning System) was used to mark the start of the marsh and information (including the GPS unit, the waypoint number on the GPS unit, and other relevant data) was entered on a data sheet. When the end of the marsh was reached, another GPS waypoint and data point was taken with similar entries on the data sheet. If necessary, intermediary points were used to mark turns, breaks, and other features of the marsh and indicated (in writing) on the data sheet. Where some condition warranted concern or interest, a digital photograph was taken and logged on the data sheet.

We performed this survey from approximately two hours before until two hours after high tide. While high water might have concealed some marshes, the high water allowed the boat to get closer to shore, increasing the opportunity of finding marshes, even when mostly submerged. The transects chosen for this boat work were run in an assortment of the environments in which the image-based identification was difficult – representing a mixture of the ‘F’, ‘M’, and ‘U’ categories of the image-based identification.

Once the data (GPS points and data sheets) were complete, the transect GPS points were converted to lines in XMap and ArcMap. The lines were combined into a single theme representing all marshes found during the boat survey. A sample is shown in Figure 6. These lines, in turn, were used to form ellipses by surrounding the line with a buffer of a specified width. Lines with a 20 meter buffer are shown in

Figure 7. The ellipses were then geographically overlain on the marshes delineated from the imagery to determine where the boat ellipses and the image-identified marshes overlapped. The percentage of boat-based marshes corresponding or overlapping with image-based marshes provided an approximation to the success rate of identification (with the previous caveats that the four years of time between the two efforts would lead to some unknown amount of change in the marshes). The selection of radii was a difficult question to answer. Figure 8 shows a set of marshes identified from imagery along with buffered (20 m) boat transects.

Figure 6: Boat transect lines from XMap

Figure 7: Boat ellipses

Figure 8: Image-identified marshes (irregularly shaped, in pink) and boat transects with buffer (more regularly shaped, in green)

The problem is that the boat could not approach the marshes closely enough for the ellipses to intersect some of the image-delineated marshes, even with a 20 m buffer surrounding the boat transects. Our solution was to produce buffered boat transect ellipses with buffer radii ranging from 20 to 200 meters. At each buffer width, the number of transect-identified marshes intersected by image-identified marshes was recorded and plotted as a percentage of the total transect-identified marshes. This function provided an asymptotic approximation to the success rate of the image-based identification, given the previous caveats of marsh changes over the four years. Figure 9 shows a plot of this function. From the plot, it appears that the image-based marsh identification successfully identifies approximately 70% as an upper limit as the allowed distance between the transect and marsh approaches or exceeds 200 meters. This is obviously not a perfect measure of the accuracy of the image identification, but does provide the best estimate possible of the success in identifying marshes.

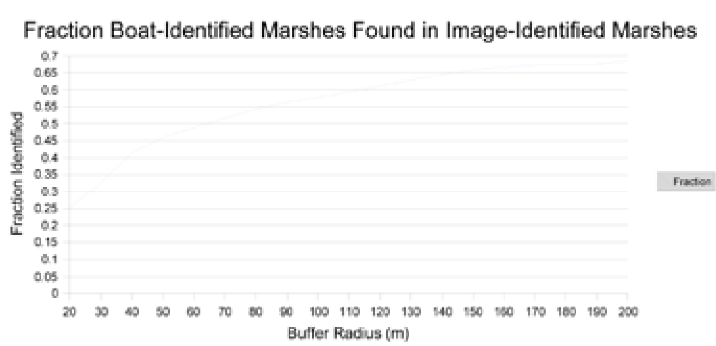

Figure 9: Fraction of the boat-based marshes identified in the Image-based marsh set as a function of buffer radius in meters.

Field Surveys
The final part of the project was the field survey of randomly selected marshes along the coast of Casco Bay. For this purpose, the Coastal Bluff Hazards GIS theme was modified slightly (to remove some features not desired for this purpose and to limit the theme to Casco Bay) and equally-spaced points were created along the resulting linear coastal outline. A subset of these points was selected consisting of sample points that were within 150 meters of one of the marshes identified during the image-based delineation process; this helped to eliminate points that might be along completely unproductive coasts (where no marshes existed). This subset of points was randomly numbered separately for the eastern and western study areas so that approximately uniform sampling frequency (samples per kilometer of coastline) could be performed. A subset of these points was then surveyed after mid-July when vegetation had developed.

At each sampling point a number of marshes was surveyed. If there were multiple marshes at each sampling point, five marshes on each side of the sampling point were surveyed. If there were fewer than five marshes (or fewer than five accessible), only those marshes present were surveyed. If the marsh present consisted of long stretches of marsh not naturally divisible into separate marshes, approximately 300 meters of marsh to each side of the sample point were surveyed; terminating points were estimated based on natural breaks (a dock, a downed tree, a panne, or other notable feature that would allow individuals in the team to generally agree on boundaries). In all, 16 sample points (six more than the original ten planned sample points) were actually surveyed, resulting in 69 marshes, including two marshes each from Little John and Cousins Islands in Yarmouth.

A common set of procedures was performed at each marsh. This included measurement of the marsh using GPS units and completing data forms for each marsh. One marsh at each sample point was treated slightly differently. In an effort to estimate marsh response to rising sea levels, a measurement was made of the estimated marsh area (perimeter) with a forty centimeter (40 cm) rise in sea level compared to the perimeter of the marsh measured.

Common GPS measurements included marking with GPS waypoints the perimeter of each marsh, the high-low marsh boundary, any significant patch of invasives (primarily Phragmites australis), and (for the one marsh at each sample point) the perimeter + 40 cm of elevation. The water-marsh boundary of the perimeter was estimated based on the presence of Spartina alterniflora in the substrate (usually silt). The high-low marsh boundary was determined based on a visual estimation of a line marking the changing dominance of low marsh species (primarily S. alterniflora) and high marsh species (primarily S. patens, but also including other high marsh plants such as Distichlis spicata, Scirpus americanus, S. robustus, and P. australis). The upper boundary of the marsh was approximated by visual estimation of plant dominance, where high marsh vegetation was dominated by upland vegetation. Large patches of invasives were measured separately and receive their own measure. The perimeter of each marsh was first marked by walking the boundaries (as described above) while recording GPS points along the route. The high-low marsh boundary was then similarly marked. During processing, the total marsh area was encompassed by the perimeter points; the high marsh area was then determined by dividing the total area at the GPS line marking the high-low marsh boundary.

At the one marsh per sample point for which response to sea-level rise was to be estimated, the process was slightly different. A laser transit was placed such that it was visible from all points in the marsh to be measured (sometimes a challenge!). As the perimeter was walked, an elevation measurement and GPS waypoint measurement were made. A second GPS waypoint measurement was made at the point uphill (uphill was an estimation based on elevation change) from each perimeter point at which the elevation was 40 cm higher. These perimeter + 40 cm points would thus form a second perimeter with an elevation of forty centimeters higher than the actual marsh, and would indicate the potential marsh response to sea-level rise (ignoring any marsh accretion or other such response to a slow rise).

During the field surveys, a portable computer running XMap was used to determine the best access route for each sample point. Property owners were approached, usually one or more days prior to the desired survey date, and permission gained for access to the marsh through their properties (it was often very helpful to be able to show the owners their properties and the marshes on the GIS software and explain the survey process). Experience led us to depend on a period of approximately four-to-five hours surrounding low tide during which the surveys of one sample point (up to ten marshes) could be performed. Two people (even one person, in a pinch) could survey the 'usual' marsh, obtaining GPS waypoints for the perimeter, high/low boundary, and invasives, and completing the data sheets. All four persons were used to survey the one marsh at each sample point for which the dual perimeters (one at a +40 cm elevation) were taken because of the need for simultaneous measurement of two related points differing in elevation by 40 cm.

Figure 10 shows two marshes that were measured at one sample point as an example of the types of results obtained after processing. The top (northern) marsh was measured for perimeter (shown in solid blue), high marsh (a single hatch in purple overlaying the high-marsh area of the perimeter), and perimeter + 40 cm (a cross-hatch area overlaying both the perimeter and the high marsh). The larger, lower marsh shows only the perimeter and the overlain high-marsh area.

At each marsh, digital photographs were taken of any unusual or interesting features, and a data packet was completed. The data packet consisted of 8 pages (for the 'usual' marsh) or 9 pages (for the marsh with a perimeter + 40 elevation measurement). The first two pages consisted of information such as a hand sketch of the marsh, the approximate location, date, marsh sequence or ID number, and brief comments about the marsh or surroundings. Four pages were specific assessment forms, used in previous and similar studies, and providing characteristics useful for estimating the 'health' of the marsh, the amount of human impact evident on the marsh, the need and potential for restoration, and the potential level of that work. Two (or three for the + 40 cm elevation measurements) additional pages contained space for GIS points and photograph ID numbers, when needed. These data packets were later scanned (for electronic records) and their information, where appropriate, entered into spreadsheets for summation and further processing.

Post field work processing consisted of scanning all data packages, collecting images, collecting GPS waypoints and appropriately labeling them, creating polygons from the appropriate points, performing statistical analysis, and organizing the information for inclusion in the final product and for archiving. This was done over the fall and winter of 2007 and the early winter of 2008 by a variety of people.

Figure 10: Marsh delineation during field survey

The largest single task was the processing of GPS waypoints taken in the field from both the field surveys and the boat transects. During the field work, the GPS units were continually monitored for the 'Satellite Tracking Lost' message or other indications of problems and, usually every couple of days, data was randomly checked for integrity as it was stored and archived for later processing. Despite that, there were sufficient GPS 'outliers' – points whose location was obviously not correct, often by large amounts – that the points required manual processing (as opposed to an automated process to create polygons from GPS points) so that obvious outliers could be removed from polygons. This involved loading sets of GPS waypoints into a GIS system (both XMap and ArcMap were used for this purpose because of the variety of people contributing their available time and experience to finishing the effort), then using the information on the data sheets to group sets of GPS points into polygons or lines representing different measurements of the appropriate marsh. The possibilities included boat transects (represented as lines, then buffered to create ellipses), marsh total perimeters, the high/low boundaries, the perimeters at 40 cm above the existing marsh perimeter, or patches of invasive plants. The result in Figure 10 represents a typical marsh GIS dataset from the field survey; the result of Figure 8 represents those of the boat transects at a 20 meter buffer width (multiple buffer widths up to 200 meters were used in order to provide a better estimate of detection ability, as explained earlier). At the end of the process, the separate files (from different sources, software, and people) were collected into appropriate groups of single-purpose files (boat transects, survey files), the files of each group combined into a single file including all the marsh subunits (perimeter, upper, invasives, and perimeter + 40cm), appropriately labeled, and archived.

Some of the statistical results of the field survey measurements of marsh area are shown in Figure 11 and Figure 12. The average area was 3570 square meters with a standard deviation of 4452 square meters; the median marsh area was 2055 square meters. These statistics are biased low due to the truncation of large marsh areas as a result of the measurement protocol – measuring only approximately 300 meters of the length of a large marsh.

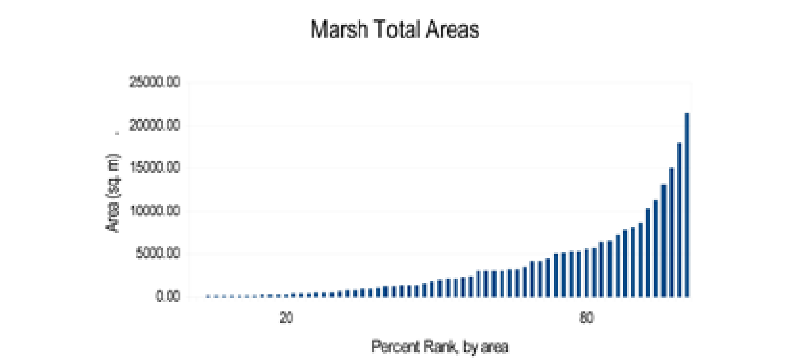

Figure 11: Marsh total (high + low marsh) areas derived from field survey measurements, ranked by area.

Finally, after data entry of the contents of the marsh assessment sheets, two scores were calculated based on the two different protocols represented by the data sheets. One protocol, referred to as the MA-CZM Assessment, derived from work performed and assessment protocols developed by the Massachusetts Office of Coastal Zone Management. This protocol was also used in several Maine-based fringing marsh studies (from whom we obtained the assessment forms). In it, 13 physical factors pertaining to the marsh or its surrounding land use and human impact are rated on a scale of 0 to 6 (6 being the higher or better score in each case). The final score is calculated by dividing the resulting sum by 78 (the maximum possible score) and expressing this as a percent (multiplying by 100) such that the score approaches 100 in the best case and 0 in the worst case (a heavily damaged marsh).

The second score was referred to as the Degradation Score and derived from previous work performed for the Casco Bay Estuary Partnership. In the original assessment, 28 physical factors or human impacts were rated from 0 to 1 (0 being the better score). In the fringing marsh version, only 23 factors were used because five of the original factors were not appropriate for most fringing marsh assessments (the protocol was originally designed to be a more general riparian or coastal habitat assessment, not strictly for salt marshes). The final score was determined by summing the individual factors and dividing by the total possible (a worst-case number of 23) to arrive at a fractional score that approached 0 in the best case and 1 in the worst.

The results are shown in Table 1.

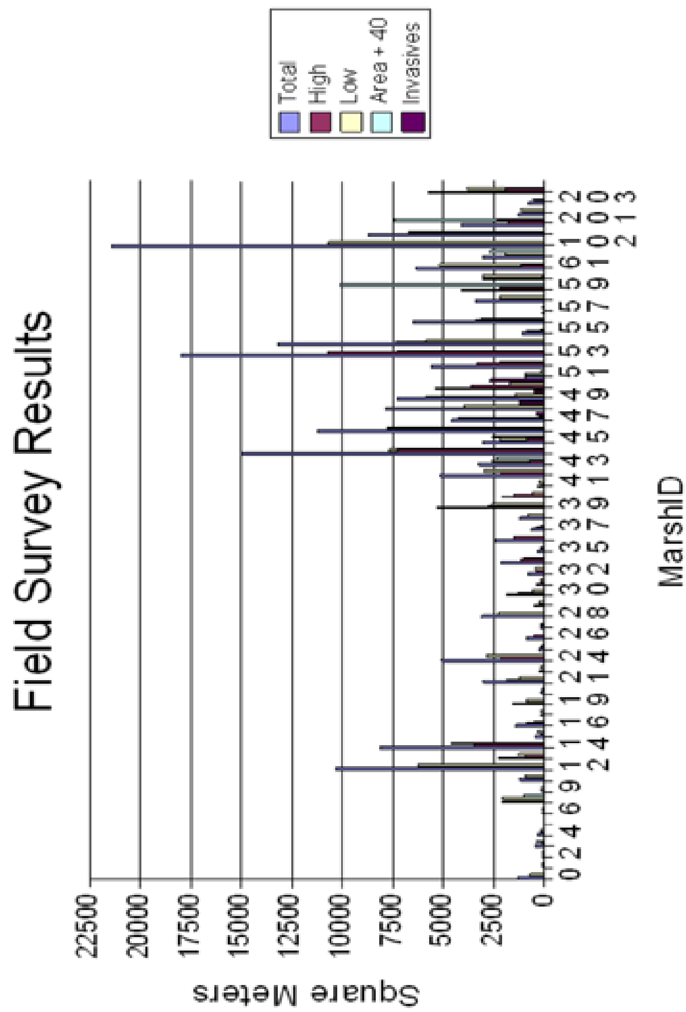

Figure 12: Marsh areas for all measured marsh units.

Marsh #	Latitude (North)	Longitude (West)	MA-CZM Score (%)	Degredation Score
00	43.72204	70.00203	60.3	0.26
01	43.72277	70.00200	46.2	0.26
02	43.75539	70.00755	57.7	0.39
03	43.75577	70.00762	60.3	0.09
04	43.75596	70.00774	83.3	0.17
05	43.75647	70.00835	69.2	0.09
06			43.6	0.65
07	43.75452	70.00603	65.4	0.39
08	43.75555	70.00527	50.0	0.30
09	43.75565	70.00500	57.7	0.26
10			46.2	0.26
11	43.75703	70.00305	43.6	0.35
12	43.75196	70.01604	56.4	0.13
13			85.9	0.13
14	43.75432	70.01547	87.2	0.26
15	43.81783	69.88580	67.9	0.17
16	43.81746	69.88602	56.4	0.22
17	43.81735	69.88615	60.3	0.30
18	43.81605	69.88642	73.1	0.09
19	43.81581	69.88663	70.5	0.13
20	43.49010	69.53160	79.5	0.17
21	43.81859	69.88602	89.7	0.00
22	43.82109	69.88468	91.0	0.13
23	43.83900	69.89177	82.1	0.26
24	43.83815	69.89246	50.0	0.17
25	43.83968	69.89083	78.2	0.09
26	43.83988	69.89070	92.3	0.04
27	43.84075	69.89038	92.3	0.00
28			92.3	0.00
29	43.88100	69.87358	100.0	0.04
30			89.7	0.09
31	43.88027	69.87352	94.9	0.00
32	43.87929	69.87381	80.8	0.30
33	43.87902	69.87370	89.7	0.04
34			94.9	0.00
35	43.86572	69.85412	73.1	0.00
36	43.86539	69.85373	92.3	0.00
37	43.86733	69.85313	83.3	0.17
38	43.85280	69.89868	76.9	0.26
39	43.85223	69.89805	84.6	0.00
40	43.85263	69.89928	88.5	0.09
41	43.85760	69.89931	87.2	0.13
42	43.85297	69.89938	71.8	0.35
43	43.81342	69.95943	66.7	0.39
44	43.81258	69.95894	76.9	0.00
45	43.70210	70.25425	50.0	0.30
46	43.70213	70.25420	43.6	0.00
47	43.70197	70.24311	64.1	0.22
48	43.70197	70.24313	76.9	0.09
49			53.8	0.52
50	43.70153	70.24278	66.7	0.30
51	43.86326	69.95036	71.8	0.35
52	43.86272	69.94932	73.1	0.04
53	43.86318	69.94801	85.9	0.09
54	43.82648	70.06587	67.9	0.39
55	43.82581	70.06897	73.1	0.30
56			78.2	0.04
57	43.86344	70.00240	66.7	0.04
58	43.86344	70.00232	85.9	0.00
59	43.86435	70.00240	84.6	0.17
60	43.86502	70.00108	88.5	0.00
61	43.86517	70.00095	88.5	0.22

Table 1: Marsh assessment sheets summary.

Conclusions and Comments

The goals of the project – aerial identification of fringing marshes in Casco Bay and the start of a restoration inventory listing of surveyed marshes – were successful. The identification of marshes from aerial imagery provided a reasonably accurate and inexpensive estimate of the location and size of fringing marshes in the study area, and the field surveys provided an assessment of the state of approximately 60 of those marshes. We hope and believe that the EPA and the Casco Bay Estuary Partnership find the results of this study useful in their future work and thank them for the opportunity they afforded all of the participants.

For the participants, it was a learning experience. Of the four of us, one had never used GIS, while the others had used only the 'traditional' ESRI products (and not frequently). The thought of learning and using a new GIS software system was initially somewhat daunting; the later reality of sharing files and exchanging data between systems to take best advantage of the software (and people's skills) would never have even crossed our minds. But the learning curve was relatively short and the rewards were high – in the end, switching back and forth was painless. Also – and here we offer our deepest appreciation to DeLorme for their gracious assistance – the project results would be poorer without the use of the XMap software and Topobird imagery. Thank you.

Finally, and certainly not least significant, although not an intended aspect of the project, the surveys provided a means of outreach to the residents living along the coast of Casco Bay. We spoke with landowners, homeowners, boat-launch owners, clammers, wormers, fisher-men-and-women, boaters... friendly people, suspicious people, curious people, concerned people... a broad cross-section of the humanity of Casco Bay. We often left them with a little more information about fringing marshes and their place in the ecosystems of Maine, and they often left us with bits of information they had, or the path to the marsh, or a parking spot for the boat trailer for a day... and support. Almost without exception, there was overwhelming support for surveying the marshes, determining necessary improvements, and implementing those improvements. Although there were certainly some heavily impacted marshes (as looking at our 'score' sheet above would indicate), it looked like the will to make the needed changes and improvements was there. We would like to thank them all for their help and support.