Drift buoys monitor surface currents driving dispersal of eelgrass (*Zostera marina*) seeds

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Eelgrass beds, which are important nurseries for many aquatic organisms, have been nearly removed from upper Frenchman Bay during the last decade. Our work efforts have shown that seed dispersal is an important part of restoration, for which water flow data are needed. This report summarizes one summer's results with a radiotelemetry technique to track surface currents.

Eelgrass (*Zostera marina* L.) reproduces both by rhizomes and by seeds. The latter, with their capability for wide and rapid spreading, are probably very important in the reestablishment of normal eelgrass beds in denuded areas. Seeds are produced along the margins of the leaves, and are dispersed when the blade breaks off. Since the blades float, the attached seeds can be carried for long distances until they finally disintegrate, dropping the seeds to the bottom[6]. For maximum efficiency, we desire to transplant flowering shoots into areas where the currents will carry the seeds to suitable substrate.

Figure 1. Drift buoy made of PVC pipe and Styrofoam®, sitting on cement block. The 4" white pipe contains the GPS/transmitter; the 3/4" spike houses the radio antenna.

Only a rough outline of current patterns in upper Frenchman Bay is available, mostly from anecdotal information. We therefore constructed “drift buoys” as shown in Figure 1 and equipped them with a combination GPS-controller-radio transmitter (Byonics MT-AIO)[3] that is set to report its position every 2 minutes. The buoy floats as low as possible to minimize the direct effect of wind on the buoy. We use a frequency in the amateur 2-meter band (GWK is a licensed radio amateur) which is received by three recording/relay stations on shore, two of which were connected to computers running the WinAPRS program[7] to log the data.

At 2-minute intervals, the unit activates its GPS receiver. When a valid position has been acquired, the controller transmits a NMEA[5] GPRMC[4] sentence containing date, time of day, latitude, longitude, and velocity, along with identification information. The position reporting resolution is 0.0001 minutes of arc or ~18 cm, which is greater than the accuracy of the GPS unit. The GPS resolution was checked with a series of 127 recordings over 63.5 min while the buoy was kept stationary. The maximum latitude error was 4.09×10^{-2} minutes of arc, which at 6000 ft (one nautical mile) per minute of arc is 245 ft (103 meters), while the standard error of these data was 6.73×10^{-4} minutes of arc, or 1.33 meters (4.38 ft). The longitude errors were similar, but since a minute of longitude is only 4500 ft at our latitude, the errors are smaller when expressed in distance units. To increase the accuracy of the velocity measurements, we calculated speed and direction from pairs of readings separated by at least 2 minutes in time.

One or two buoys were deployed at a time during parts of 37 days between July 1 and October 9, 2009. Variation in the time of high tide provides a range of tide conditions during daylight hours. We collected nearly 18,000 individual records; after rejecting duplicate and spurious data (recorded while the buoy was on the dock, washed ashore or in transit) the remaining 8522 records are the valid data set.

The sorting and plotting programs were written in JustBASIC[6]. For each running pair of points, we calculated the differences in latitude and in longitude (minutes of arc), converting these to distances in nautical miles. We then calculated the distance and direction between each pair of points, expressing the result as a velocity vector (speed and direction).

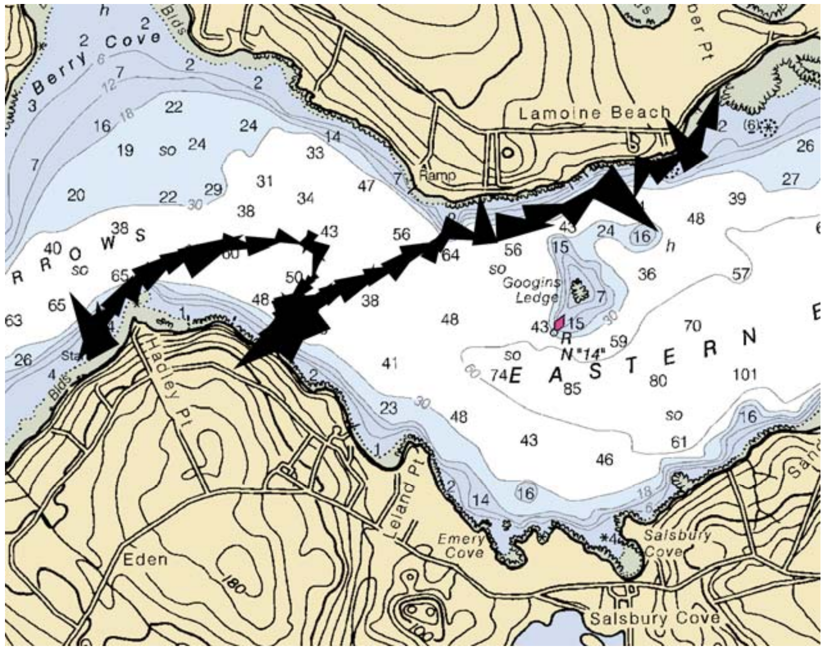

Figure 2. Example of single buoy track, starting just west of Hadley Pt. at 12:14 GMT (08:14 EDST) August 25. High tides were at 06:56 GMT (02:56 EDST) and 19:17 GMT (15:17 EDST). Record ended off Lamoine Beach at 20:06 GMT (16:06 EDST) . The arrows indicate direction of movement; arrow size indicates speed (0.1 to 1 kn.) Only every 4th point plotted, for clarity.

We plotted the data on a nautical chart, using UIView[2] which is designed for real-time plotting of amateur APRS data and transferring the data to ArcGIS[1] for presentation. Figure 2 shows an example of a single track, translated to GIS format and plotted on a nautical chart of the area. The buoy was released near our restoration area, which has had an increasing (now 4-8%) eelgrass coverage over the past two summers. It started east on the ebb tide, changed direction during the height of the flood, but subsequently resumed its easterly movement, running parallel to the Lamoine Beach shore. Many similar observations show a tendency for currents to flow from the restoration area onto the Lamoine shore, accounting for the incipient eelgrass beds recorded there in the summer of 2009.

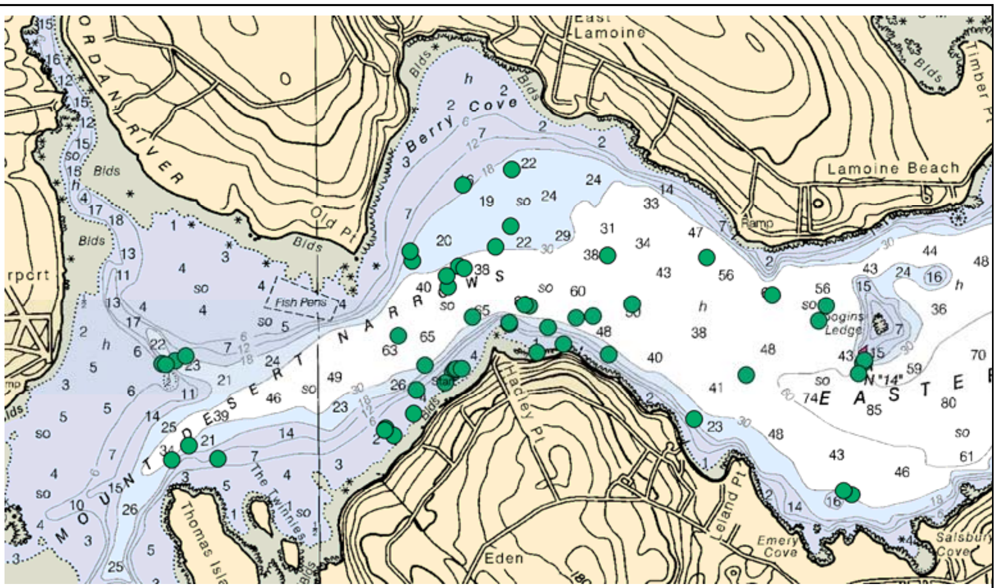

Figure 3. Starting points of the 53 records recorded in the summer of 2009.

It is difficult to summarize the 53 valid drift runs obtained, since current speed and direction must be correlated with latitude, longitude and time of tide cycle, at a minimum. Figures 3, 4, and 5 are our attempts at this process. Some parameters are relatively easy to present. For instance, the starting positions ideally should be evenly distributed both in space (latitude and longitude) and time (relative to the tide cycles). Spatial distribution is tested by plotting the initial positions of each day's record, as shown in Figure 3. There are some obvious gaps (notably Berry Cove and west of Thomas Island) which are targets for future work, and there are some areas of concentration, such as the region around the Hadley Point restoration reserve, which was obviously of interest to this study. Practical considerations of distance from the laboratory and likelihood of the buoy's running aground were also factors, but this does not seem to have severely biased our conclusions.

To check the distribution within the tide cycle, we broke the data into 30-minute "bins" indexed to the previous high tide, calculated the velocity and direction of movement between each pair of points, and plotted these against location as a set of 25 charts covering the 12 hour 26 min tide cycle. The 25 bins contain 337 ± 6 records each, correcting for the short-time 25th bin, showing the expected uniform distribution of records across the tide cycle. The distribution of velocities varies greatly across the tide cycle, as might be expected. Figure 4 shows the average direction and speed for the 25 bins. During the ebb tide there is an easterly trend to the current, and the speed is also maximum at these times. However, the flood tide (bin 12 and above) does not show a corresponding westerly current. Two factors could account for this observation. First, the prevailing winds are from the west, and tend to produce surface currents which add to the tidal currents. The water would then be returned in a sub-surface current with the opposite orientation. Secondly, there is a considerable fresh water inflow from Northeast Creek, which varies in magnitude but is always present. This would establish a net outflow from Eastern Bay toward the east (flow through the narrows to the west is minor) and would particularly intensify the current at the surface. In the absence of complete hydrographic data, these remain speculations, but it is interesting that Eastern Bay is one of the few portions of the Maine coast which has never been closed to mussel harvesting due to red tide (*Alexandrium* sp.); this prevailing outflow might prevent the organism from entering the bay.

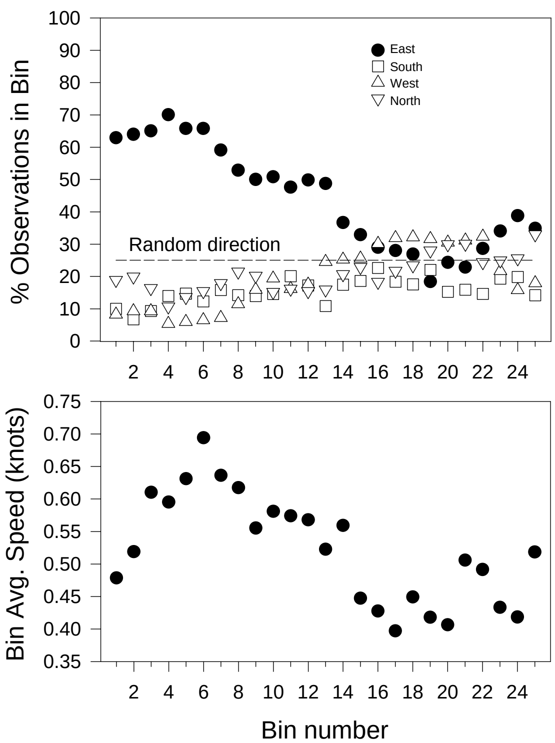

Figure 4. Averages of the direction (above) and speed (below) components of the velocity vectors for the 8525 points collected, as sorted by 30-minute periods after high tide. During the ebb tide (~bins 0 to 12) the percentage of observations scored as easterly (45° to 135°) is well above random expectation, while the other 3 quadrats are low, since the values must sum to 100%. Likewise, the speed peaks at bin 6, as expected. However, during the flood tide (~bins 12 to 24), the direction quadrat percentages are nearly equal, and there is no marked peak in the average speed.

In an attempt to represent location, time and current flow, we laid down a rectangle 3.75 min (nm) in latitude by 7.5 min (5.6 nm) in longitude, with its southeast corner at 44°25.25' N by 68°14.25' W, which covers the recorded region. This rectangle was divided into a grid of 450 blocks, each 0.25 min on a side, and the data from within this block was averaged and plotted on the center of this block. Clearly some of these blocks will be unoccupied, as they fall on land, and some blocks will have a mid-point on land although there is valid data from that portion which falls on water. For each 30-minute tide bin, each data point was assigned to its position block, and the average velocity and direction for all points in the block was calculated. Figure 5 shows the results for the sum of bins 15 through 21, 7.7 to 11 hours after high tide. This covers the times for which the maximum flood currents should be observed. If the currents were exclusivly tide-driven, one would expect this period to produce currents headed into Eastern Bay, that is, a westerly trend. Clearly this is not the case, and the velocity vectors are found in a range of orientations and magnitudes.

It is clear that even this large number of data points is not sufficient to give a complete picture of the currents in Eastern bay. We can, however, form some preliminary conclusions. One is that there are often currents which could carry propagules from our transplanted area west of Hadley point toward the Lamoine shore, which seem to be the reason for the recent identification of young eelgrass beds at the latter sites. We need to identify other trends as a guide to future transplantation efforts. Secondly, averaged over the tide cycles, there seems to be a general eastward trend to the currents, as might be expected from the fresh water input to Eastern Bay (Northeast Creek, primarily) and the prevailing westerly winds. We noticed many records in which the buoy movement is circular or contrary to the assumed tidal current flow, which would lead to leaf fragments "stalling" in eddies. This may be very important for determining the locations of seeding in *Zostera marina*.

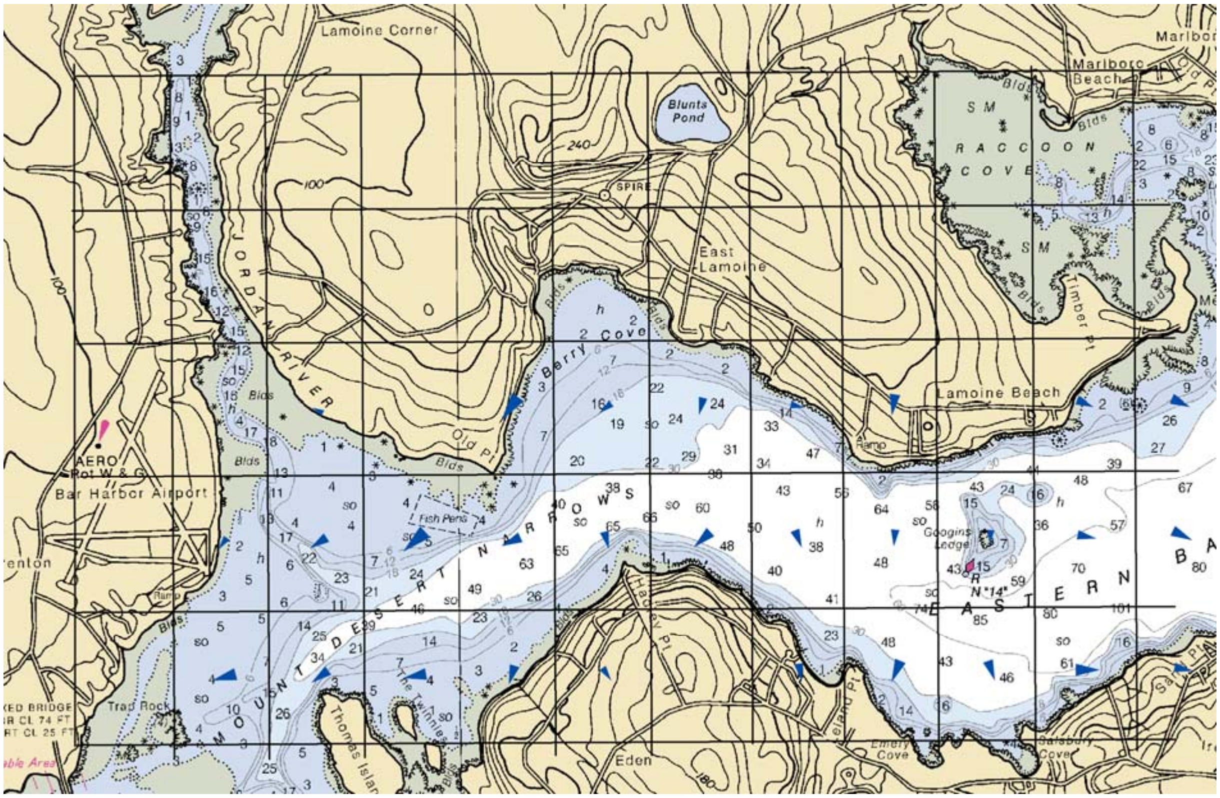

Figure 5. A plot of the data from 7.5 to 11 hours after high tide (during the flood portion of the cycle), broken into spatial blocks 0.5 minutes on a side. (Not rectangular, since minutes of longitude are smaller than minutes of latitude.) The arrowhead in the center of each block shows the average current direction and speed for these data. While one might expect a westerly trend on a flood tide, the average currents are seen to flow in various directions depending on position.

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