San Francisco Estuary
Wetlands Regional Monitoring Program

Data Collection Protocol
Plant Community Structure of Intertidal--Upland Ecotone

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Version 19
May 28, 2010

Introduction

This protocol is designed for assessing the ambient condition of vegetation and the effectiveness of vegetation management in the ecotone between intertidal areas and uplands.

The intertidal-upland ecotone of San Francisco Bay functions as a refuge for intertidal wildlife (Goals Project 1999, Baye 2008), including the endangered California clapper rail and salt marsh harvest mouse (USFWS 2010). It tends to be especially rich in plant species (Goals Project 2000, Baye 2008), although non-native species are often abundant (Fetscher et al, 2009).

This ecotone has been severely impacted by the conversion of tidal wetlands into agricultural lands and commercial salt ponds, and by the filling of marshes for residential and industrial development (Collins and Grossinger 2004). Bayshore development has encroached into or through the ecotone in many areas. Hundreds of miles of levees have been constructed atop the ecotone to protect adjacent land development from extreme high tides. Railroads, pipelines, and transmission corridors commonly trace the ecotone along the bayshore and have disrupted the ecotone to varying degrees. Much of the existing ecotone is now confined to the bayward facing slopes of earthen levees and road grades. The few relatively intact remnants of the historical ecotone have been subject to decades of farming or ranching.

The ecological functions of this ecotone have been gaining recognition within the regional community of natural resource scientists and managers. This is evident by the increasing number of efforts to restore and protect the ecotone. However, there are scant data about the success of different restoration efforts. Carefully collected data about the success of different plant species at different positions within the zone under different management regimes is needed to inform restoration design. This information can be developed through dedicated research and from restoration projects that use standard methods of data collection to track restoration outcomes. This protocol is intended to meet the need for standardized data about the responses of the ecotone plant community to onsite vegetation management. This protocol can

also be used in broader surveys of the ambient condition of the ecotone. Standardized use of this protocol will allow comparisons between local management actions and ambient conditions.

In this protocol, plant community structure is assessed in terms of the abundance of each plant species and bare ground observed during the assessment (i.e., the percent of a specified area of land surface within the ecotone that is covered by each species or bare ground). Information about the abundance of native and non-native species, planted species and other species is automatically developed by the database. These data are particularly useful for characterizing the distribution of common species that make up the bulk of the biomass in the ecotone and less valuable for identifying rare species. These data can also help assess the value of the ecotone as wildlife habitat. If these data are collected at sites before and after they are restored, the data can be used to asses the effects of the restoration efforts.

Many kinds of additional data might be collected along with the data on absolute percent cover of plant species. For example, measures of plant vigor (i.e., plant height, leaf size, amount of flowering or seed-set, etc), plant patch size, and soil fertility provide additional information about plant community structure and site potential that are sometimes more sensitive to management actions than percent cover. At this time, this protocol is restricted to the measure of percent cover to minimize monitoring costs.

With the advent of Global Positioning Systems (GPS) and web-based Geographic Information Systems (GIS), data collection in the field can be integrated with data management and visualization. This protocol is designed to encourage collaborative efforts to learn from restoration projects by standardized applications of conventional scientific methodologies and new Information Technology (IT) to compare projects to each other and over time. This protocol compliments the one for monitoring tidal marsh vegetation (Vasey et al., 2002).

Definition of the Tidal Marsh Ecotone

In concept, the intertidal-upland ecotone is a zone of decreasing tidal influence extending landward from tidal marshland or tidal flat up to or slightly beyond the maximum landward effect of tidal waters on plant community structure. The overall breadth of the zone decreases as its steepness increases. Steep shores have very narrow ecotones. Long alluvial valleys sloping gently to the intertidal zone can have very broad ecotones (Collins and Grossinger 2004). Due to the shape of the tidal curve (i.e., the pattern traced by plotting the rise and fall of the tides over time), plus friction caused by vegetation through which the tidal waters flow, the frequency and duration of tidal inundation decreases exponentially with distance landward through the ecotone. Near the upper limit of the ecotone (i.e., near the top of the tidal curve), large percent changes in the frequency and duration of tidal inundation correspond to slight changes in elevation. That is, the top of the ecotone might be inundated once every few years and slightly higher places are never effectively inundated. The vegetation of the lower limit of the ecotone tends to resemble the adjacent tidal marsh plain. With distance landward, the vegetation shifts to species indicative of the upper limits of regular tidal action, and then to mixtures of these species and upland species. The upper limit of the ecotone is indicated by only traces of vegetation affected by the tidal waters. The width of the ecotone can be increased by wave run-up, boat wakes, and extreme high tides during storms, and the deposition of salts picked-up from the intertidal zone and carried landward by onshore winds.

For the purposes of this protocol, the following practical definitions apply.

- The upland ecotone is defined as the area extending bayward from the backshore onto the adjoining marsh plain or tidal flat for a distance of 2.0m, and extending landward from the backshore to whichever of the following two elevation contours is lower: (A) the top of any earthen levee, road grade, or other artificial topographic feature that can support vegetation or (B) an elevation contour 2.0m higher than the nearby marsh plain, or, if there is no marsh plain nearby, 2.5m above the maximum height of adjacent tidal flat.

- The backshore is defined as the approximate landward extent of daily tidal processes that influence the topography of the ecotone and the distribution and abundance of plant species indicative of the local tidal marsh plain. This is usually a topographic contour slightly higher than the local Mean Higher High Water (MHHW) datum.

- A marsh plain is defined as a flat area at least 100m^2 having essentially uniform slope that is subject to regular tidal inundation and that supports at least 5% cover of vegetation, 75% of which consists of plants restricted to tidal marshes. Tidal flats meet all these criteria except that they lack 5% cover of vegetation. The indicative species of the tidal marsh plain vary with salinity regime. To identify these plant species for any tidal marsh, the interior reaches of the marsh plain equidistant from any tidal marsh channels or pannes must be examined. Typical marsh plain flora for saline and brackish regimes include, but are not limited to, *Salicornia virginica* (pickleweed), *Jaumea carnosa* (fleshy jaumea), *Distichlis spicata* (salt grass), *Juncus balticus* (Baltic rush), *and Triglochin maritimum* (seaside arrowgrass).

  In the case of tidal marsh restoration sites that do not yet support 5% cover of tidal marsh vegetation, the backshore is defined as the landward extent of the non-vegetated tidal flat. Most restoration sites have at least a narrow band of marsh vegetation that can be used to delineate the backshore based on the field indicators provided below (see discussion of Sample Strata in section on Sample Design).

There are not a lot of data to validate the prescribed upper limit of the ecotone (i.e., see the first bulleted definition in the list of definitions immediately above). A summary of known elevations and ages of tidal marsh plains around San Francisco Bay suggests that they gain elevation as they age, and that the elevations of mature plains range from about Mean High Water (MHW) (marshes between 100 and 200 years old) to about 0.2m above MHHW (marshes much older than 200 years), and that most marsh plains around San Francisco Bay are less than 200 years old (Goals Project 1999). It might therefore be assumed that most marsh plains have an average elevation between MHW and MHHW. Based on the readily available tidal height data from gauges around the Bay that meet federal standards for accuracy and precision (http://ports-infohub.nos.noaa.gov/hq/bench_mark.shtml?region=ca), extreme high water events (the highest observed water levels) range in elevation from about 0.4m to 1.2m above local MHW, and from about 0.2m to 0.9m above local MHHW, depending in part on tidal range. Higher values are for areas with greater tidal range. Assuming that the *minimum* upper limit of the ecotone is equal to the *maximum* observed water level, and that the marsh plain is about halfway between MHW and MHHW, and assuming a moderate tidal range, then the upper limit of the ecotone probably has a minimum height of about 1.0m above the marsh plain. The National Ocean Survey (NOS) found the average upper limit of salt-tolerant vegetation to be

0.8m above the marsh plain at Point Pinole in San Pablo Bay (NOS 1975). At Palo Alto, Hinde (1954) observed pickleweed (*Salicornia virginica*) at about 1.2m above the average marsh plain. NOS (1975) observed alkali heath (*Frankenia salina)* slightly more than 1.3m above the marsh plain. Based on these data, it seems reasonable to assume that the maximum upper limit of the ecotone, as directly affected by the tides, is probably not more than 1.5 m above the height of the nearby marsh plain, and is certainly not more than 2.0m above the marsh plain. The 2.0m value used in this protocol is further justified by assuming that some minimum amount of upland area higher than the tidally-influenced vegetation is an upward extension of the ecotone, just as the margin of the marsh or tidal flat is a downward extension of the ecotone. With regard to tidal flats, it can be assumed that the lower limit of tidal marsh vegetation (i.e., the upper limit of tidal flats) corresponds to local Mean Tide Level (MTL) (Atwater and Hedel 1976), and that the average difference in elevation between marsh plains (i.e., the elevation midway between MHW and MHHW) and MTL around the Bay is about 0.5m (based on the tidal gauge records). Therefore, the upper limit of the ecotone is probably about 2.5m above the maximum height of the nearby tidal flat (i.e., the marsh plain is 0.5m above the flat, and the top of the ecotone is not more than 2.0m above the marsh plain).

However, tidal marsh vegetation has been observed at elevations greater than 2.0m above the adjacent marsh plain. In uplands sloping gently upward from tidal marsh and subject to strong onshore winds, the lead author has found *Frankenia salina* and salt grass (*Distichlis spicata*) mixed with upland grasses at elevations more than 3m higher than the adjacent baylands. In a recent description of the tidal-marsh-upland ecotone of San Francisco Bay (Baye 2008), field photographs clearly show the ecotone, as defined by distinctive vegetation, extending more than 2m above the marsh plain at China Camp (San Pablo Bay), and elsewhere. Ecotone restoration projects commonly consider the entire bayward faces of shoreline levees as areas of potential ecotone, and these faces commonly extend more than 2m above nearby tidal marshland. Coyote brush (*Baccharis pilularis*) is considered a tidal marsh plant species (Baye 2007), in part because it occupies natural levees along tidal marsh sloughs. It is commonly regarded as a species well-suited for the upland reaches of the ecotone, although it also occurs at much higher elevations. Given these observations, the upper elevation limit of the ecotone as prescribed for this protocol is conservative. It should be revisited as new field data for delineating the ecotone are developed. The upper limit would ideally be defined using local tidal height data collected near the backshore. Such data are very rare at this time.

Personnel

Anyone who can identify wetland vascular plant species and who understands this written protocol should be able to conduct this sampling, if provided with appropriate orientation and supervision.

All field personnel must adhere to practices that ensure their safety and the well being of plants and other wildlife inhabiting the ecotone and adjacent habitats. All personnel must know and adhere to the policies and laws that govern access to, and activities within, the ecotone. For example, access can require written permission to cross private lands, and activities within the ecotone might be constrained by policies protecting threatened or endangered wildlife. Contact local land owners and the Endangered Species Office of the U.S. Fish and Wildlife Service for more information about restrictions and requirements for accessing the intertidal-upland ecotone.

Primary Monitoring Questions

The protocol is designed to answer the following questions.

- What is the plant species richness of the ecotone?

- Which plant species dominate the ecotone?

- How do plant species richness and dominance vary across the ecotone?

- Does plant species richness or dominance vary with restoration design or practice?

- Do the effects of restoration design or practice vary across the ecotone?

When used as directed as part of a monitoring program, this protocol can provide basic information about the status of the plant community of the ecotone in relation to restoration and management practices. If applied consistently over time and from one site to another, it can be used to compare sites, compare restoration and management practices, and to track basic temporal changes in plant community structure. However, it provides little information about such factors as plant vigor, the distribution and abundance of rare plant species, or the wildlife support functions of ecotone vegetation. This protocol could be used to assess such factors if the relevant data were added to this protocol.

This protocol is designed to elucidate spatial and temporal changes in plant community structure of the ecotone, based on standardized monitoring. The monitoring data can be used to develop hypotheses about the causes and consequences of the observed patterns, but are unlikely to be suitable for testing the hypotheses. Understanding cause-and-effect relationships requires specially designed experimentation. This protocol might be used in hypothesis testing, depending on the experimental design.

Monitoring Design

Overview

A stratified-random sampling approach is used to characterize the plant community of the ecotone with regard to the abundance of plant species within 2-4 elevation strata. Additional data on the status of plant species as native or alien, and on site-specific factors such as restoration design, restoration practice, management activities, and salinity regime are derived from the sampling data plus basic information about site characteristics and history.

Assumptions

The underlying assumptions of this monitoring design are listed below.

- Percent cover of plant species varies with elevation across the intertidal-upland ecotone.

- Percent cover of plant species is sensitive to restoration project design and practices, including removal and/or planting of vegetation, fertilization, irrigation, mowing, and herbicide application.

- The relationship between the percent cover of plant species and restoration design and practice varies with elevation across the intertidal-upland ecotone.

Sample Universe

The sample universe (aka sample frame) depends on the purpose of the assessment. For example, when the protocol is applied to an ambient survey, the sample universe consists of all areas of the ecotone within the geographic scope of the survey. When the protocol is used to assess individual restoration projects, the sample universe includes the entire ecotone within the project area that is subject to on-the-ground restoration or management actions. The sample universe of a project can grow as the actions expand across the project area.

Sample Site

A sample site is a continuous portion of ecotone at least 50m long, but not longer than 500m, and having essentially the same width and overall plant community appearance. The following criteria should be used to decide on the end points of a sample site.

- A site *should be* between 50m and 500m long. These are guidelines and not rules.

- The plant community must have the same *overall appearance* throughout. Some variability in plant community structure along a site is expected.

- A site must not incorporate major differences in restoration design or management activities (e.g., differences in irrigation, species removed or planted, etc.), or elapsed time since the management activities were initiated (i.e., all parts of a given site should represent the same stage of plant community development or succession). The complete history of a site is seldom known. But, major differences in historical treatments or impacts should not be incorporated into a site. This is an important criterion for elucidating differences in plant community structure between different practices and different times. If sites include areas subject to different activities, or that represent different periods since the activities were begun, then the differences in plant community between practices and periods cannot usually be discerned.

- Each upland sample stratum within a site (see section title "sample strata" immediately below) must be at least 1m wide to accommodate the standard $1.0m^2$ sampling frame. There is no maximum width for any upland stratum, *but except for the special situation of a very broad ecotone* (see paragraph 3 of Step 4 in section titles "Sample Strata" below), there can be no more than 3 upland strata for any site. Some ecotones are so narrow that they consist of only 2 strata, the intertidal stratum and one upland stratum.

Sample Strata

Each sample site shall be separated into elevation strata. The purpose of these strata is to account for the assumed effect of tidal elevation (i.e., frequency and duration of tidal inundation or wetting), on plant community structure. Without such stratification, the sample data tend to be too variable to detect differences in plant community over time or between sites. The following procedure shall be used to stratify a site.

1. For each sample site as defined above, identify and mark the approximate location of the backshore. The backshore is an elevation contour; the entire backshore of a site has the same elevation. In concept, the backshore is the landward extent of daily tidal processes that directly affect the topography of a site and the distribution and abundance of marsh

plain plant species within the site. Boat wakes, extreme high tides associated with winter storms, and the landward distribution of salt deposited by onshore winds are disregarded in backshore identification. The backshore has a variety of field indicators that should be used together to identify the likely position of the backshore (Figure 1). These indicators include the following.

- In general, the backshore is slightly higher than the adjacent marsh plain (or tidal flat if there is no adjacent marsh plain).

- The shoreline often has a wave-cut bench or other break in slope created by tidal action. The top of the bench is usually slightly lower than the backshore.

- The landward extent to which plants indicative of the marsh plain comprise at least 75% absolute cover tends to indicate the backshore in mature ecotones.

- Native shrubs such as gum plant (*Grindelia stricta*) and coyote brush (*Baccharis pilularis*) sometimes inhabit the backshore. The bases of the trunks of the lowermost individuals of these species are sometimes a good indicator of the backshore.

- In the absence of shrubbery, fencing or other obstructions to the landward distribution of wrack (i.e., floating trash, wood and plant debris, and other detritus carried by the tides), the average height of the wrack line tends to be slightly higher than the backshore. Where shrubbery or other obstructions prevent wrack from freely moving landward to the limits of the tides, the wrack tends to settle on the marsh plain and is therefore somewhat lower than the backshore.

- Independent delineations of the backshore by different workers at a site should not differ from each other by more than 25cm *in height,* relative to the adjacent marsh plain or tidal flat.
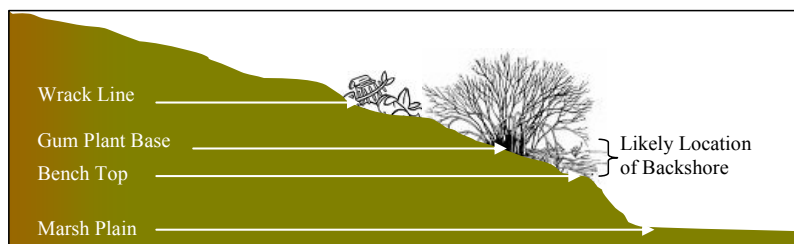

Figure 1: Conceptual diagram of the likely position of the backshore in relation to various field indicators.

2. Determine the minimum width of the portion of the transition zone that extends landward from the backshore. Inspect the entire site and locate areas where the width seems minimal. Measure width at these locations by holding a tape in the air parallel to the ground surface between the backshore and the landward limit (i.e., upper edge) of the ecotone. Use more appropriate of the two following alternative definitions of the ecotone to estimate its upper limit.

The upland ecotone extends landward to whichever of the following two elevation contours is lower: (A) the top of any earthen levee, road grade, or other artificial topographic feature that can support vegetation or (B) an elevation contour 2.0m higher than the nearby marsh plain, or, if there is no marsh plain nearby, 2.5m above the maximum height of adjacent tidal flat.

3. The lower-most stratum of a site always consists of an area of the intertidal marsh or tidal flat 2.0m wide that adjoins and parallels the backshore (Figure 2).

4. This step determines the number of upland strata and their standard width for any site. Most sites will have 3 upland strata of equal width. Divide the minimum ecotone width from step 2 above by 3. If the resulting quotient is between 3 and 10, the upland portion of the ecotone will have 3 strata, each as wide as the quotient. For example, if the upland portion of the ecotone is 3m wide, it will have three upland strata each 1m wide. If the upland portion is 12m wide, each of the three upland strata will be 4m wide.

    > **Comment [JC2]:** See JC comment 1 above.

    If the quotient is less than 3 but greater than 2, divide the overall minimum width of the upland portion of the ecotone by 2, and the upland portion will have two strata, each as wide as the quotient. For example, if the minimum width of the upland portion is 2.75m wide, then it is only wide enough for 2 strata, each of which will be about 1.3m wide (i.e., 2.75/2 = 1.375, rounded to 1.3). If the width is less than 2m, then the upland portion of the ecotone comprises a single stratum.

    Very broad ecotones (i.e., sites where the minimum width of the upland portion of the ecotone is greater than 30m) require special treatment. In the few examples examined thus far, the broadest area of the upland portion of the ecotone corresponds to the lowermost upland stratum. The resulting variability in community structure across this one stratum can increase the variance of the sample data and reduce the ability of the data to discern differences between this stratum and neighboring strata. The solution is to further stratify the stratum. If the upland strata are each more than 10 m wide, based on Step 2 above for determining stratum width, subdivide the lowermost upland stratum into two substrata of equal width (Figure 3).

    > **Comment [JC3]:** This situation is probably rare at this time in SF bay Area. It occurs is a few places in North Bay and around Suisun, but might be more common in the future if diked baylands in these areas are breached.
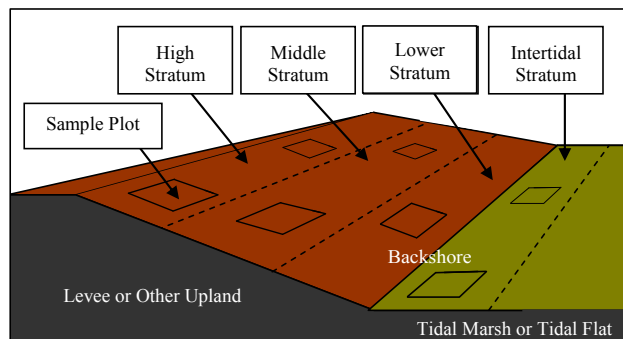

Figure 2: Conceptual diagram of tidal marsh-upland ecotone sample strata, showing some sample plots (black rectangles) in each stratum for a site wide enough for three upland strata.
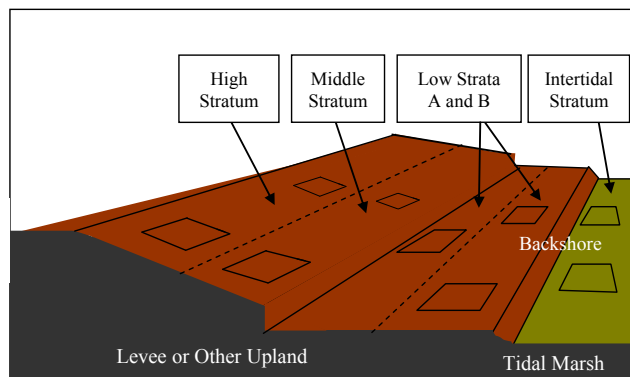
Figure 3: Conceptual diagram of an ecotone with an especially broad low upland stratum, where plant community structure tends to change rapidly with changes in elevation. To minimize the sample variance in this especially variable part of the ecotone, the stratum is further stratified into parts A and B.

Most sites are not completely uniform in their width. The upland portion of a site might be wide enough for three strata in almost all places and two strata elsewhere. As explained in the section below on data collection, the number of strata can vary within a site, so long as the dominant number is based on the minimum width of the upland portion of the ecotone, as instructed in this step.

Sample Plots

Sample plots are square areas $1m^2$ in size (100 cm to a side) that are randomly selected within each of the sample strata.

Sample Size and Sample Plot Selection

Sample size is the number of plots per stratum at one site. Sample size can differ between strata at a site, and between sites. The following process for determining sample size is designed to assure that the sample for any given stratum adequately represents the abundance (absolute percent cover) of each common plant species occurring in the ecotone.

Candidate sample plots are randomly selected for each stratum at each site according to either of the two following procedures. This is referred to as the sample draw. One alternative procedure uses high-resolution aerial imagery in a Geographic Information System (GIS). However, use of GIS requires access to it plus GIS expertise that are not essential for this protocol. The field alternative can be used when a GIS is not available.

GIS Alternative

1. In a GIS, draw the boundaries of the sample strata on recent-vintage, 1-m pixel resolution or higher resolution digital aerial imagery (i.e., recent NAIP imagery or suitable site-specific imagery).

2. Using the GIS, create a line down the center of each stratum, and measure the length of these centerlines.

3. Using the GIS, divide the centerline of each stratum into a continuous series of non-overlapping, 1-m long segments. For example, if the stratum centerline is 100m long, it will have 100 1-m long segments.

4. For each centerline, assign a unique alpha-numeric code to each 1-m long segment.

5. For each centerline, determine how many 1-m long segments in aggregate equal 10% of the total length of the centerline. For example, if the centerline is 100m long, then 10 1-m long segments comprise 10% of the centerline length. This is the sample draw size.

6. For each stratum, randomly select the number of 1-m segments equal to the sample draw size. The randomly selected cells equal the sample draw.

7. The middle of each selected 1-m long segment of the sample draw will correspond to the center of a sample plot. Mark the latitude and longitude of the middle of each selected 1-m long segment on the map of each stratum to produce a map of the sample plots.

8. The sample plots can be located in the field by inputting their unique latitude and longitude coordinates as way-points into a Geographic Positioning System (GPS) with 1m horizontal accuracy, or by using the sample plot map from Step 7 immediately above.

Field Alternative

1. Stretch one or more 100-m long measuring tapes graduated in centimeters along the backshore of the site. A 250-m long site will have 2 and one half 100-m long tapes stretched out end–to-end. A 500-m long site will have 5 (five) 100-m long tapes stretched end-to-end. Make sure the tapes follow a single elevation contour, plus or minus about 10cm in elevation. Leave the measuring tapes in place until all the strata are sampled. It is helpful to stake the backshore at regular intervals and to attach the tapes to the stakes above the vegetation. A survey level can be used to stake the backshore.

2. Determine the sample draw size based on the length of the backshore in meters (i.e., the length of the site). If the entire backshore is 100-m long (i.e., if the site is 100m long), each stratum will have a total number of 100-1 = 99 possible plots (the 100-m distance is excluded). The sample draw size equals 1/10 (one tenth) of the site length. If the backshore is 100m long, then the sample draw size is 10. If the backshore is 500m long, the sample draw size is 50.

3. Randomly select the plots for the sample draw. One method is to separately number equal-size slips of paper from 1 to the number equal to the length of the stratum in meters minus 1 meter (i.e., if the stratum is 100m long then separately number 99 pieces of paper from 1 to 99); mix the pieces of paper thoroughly in a hat or other suitable container; withdraw the number of slips equal to the sample draw size (as determined in Step 2 immediately above). Each selected slip of paper identifies the location of one sample plot in the sample draw for one stratum, in terms of its distance in meters along the backshore.

Withdraw the slips of paper one at a time, and record their numbers in the order in which they are withdrawn.

4. Repeat steps 1-4 for each stratum of each site. It is essential that a separate sample (i.e., a separate set of sample plots) be drawn for each stratum. Note that all the strata will have the same length, and will therefore also have the same number of sample plots (i.e., Steps 1 and 2 only need to be done once per site), but the locations of the plots that are actually used will not necessarily be the same for any two strata because the plot locations are randomly selected separately for each stratum.

    Note: for any given site, the sample strata will stay the same from one sample period to another, but each sample period will require a new sample draw for each stratum.

Finalizing the Sample

Finalizing the sample means deciding how many plots from the sample draw have to be collected within each sample stratum to adequately represent its plant species richness and the abundance of the common plant species. It is not likely that the entire sample draw will have to be used to meet these objectives. The sample is finalized separately for each stratum.
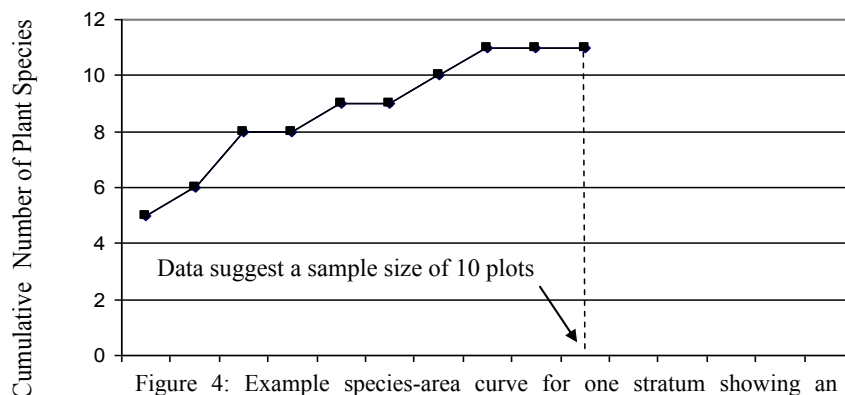
Figure 4: Example species-area curve for one stratum showing an asymptote at eight sample plots, indicating that for this stratum only 8 plots are needed.

The sample is finalized as data are being collected. Finalizing the sample is part of data collection. The process of finalizing the sample is explained separately here, but is actually integral to data collection, which is outlined in the next section of this protocol.

1. The sample plots for each stratum are visited in the order in which they were selected into the sample draw. The first plot randomly selected is visited first, regardless of where it is along the stratum. The plot selected second is visited second, and so on.

2. The last kind of data collected at each plot is the total number of "new" species occurring at the plot. "New" species are species that have not been observed in previous plots within that stratum. All the species occurring in the first plot are counted as "new."

3. As data collection proceeds from one plot to the next within a stratum, a graph is constructed showing the cumulative number of "new" species observed (Figure 4).

4. Sampling stops for a stratum when the number of "new" species does not change for three consecutive plots (Figure 4). This means that each stratum will have a minimum sample size of 3 plots.

5. The data on abundance (i.e., absolute percent cover) for all the plots within a finalized sample are used to identify the dominant plant species, using the following method adopted from the US Army Corps of Engineers (USACE 2008). This step will be conducted after the data have been collected.

   A. For each species, add together the plot-specific values for absolute percent cover. There should be one value for each species in the sample for each stratum.

   B. For each stratum, add together the species-specific values from step 5A above.

   C. For each species, divide its value from step 5A by the value from step 5B. Each species will thus have a single percent cover value for the stratum as a whole.

   D. List the species in descending order of their percent cover, using the values for each species calculated in step 5C above.

   E. Starting at the top of the list from step 5D above, and proceeding consecutively down the list, select the species that, when their values for percent cover are added together, the sum exceeds 50%. These are considered dominant species. If the first species has a cover value $\geq$ 50%, it is a dominant species. All species of equal cover value that contribute to meeting this requirement must be selected.

   F. Identify any other species that by themselves have an overall percent cover for the stratum as a whole of at least 20%. These are also considered dominant species.

6. The percent cover data for the species identified as dominant in step 5D and 5E above are used in a power analysis to determine whether the sample size determined based on the species-area curves is adequate to be either 80% or 95% certain of estimated differences in percent cover between any two strata for any observed plant species.

Data Collection

Data collection entails field-based measurements of the selected parameters of plant community structure for all the sample plots during one sample period. For each site, the following sampling steps shall be conducted in the following order.

1. Begin data collection at the first plot selected into the sample draw for the intertidal stratum. Locate the distance along the tape measure that corresponds to this first plot.

2. At this location along the tape, extend a second tape 1.0 m perpendicular to the backshore onto the marsh plain.

3. A square plot frame having an area of 1m^2 (100 cm per side) is carefully lowered onto the marsh plain, such that the 1.0m mark of the tape is at the center of the frame, without undo disturbance to the plant cover within the plot or around it. Do not disturb the adjoining upland stratum. Each intertidal stratum plot should cover the distance across the marsh plain from 0.5m to 1.5m away from the backshore.

4. Collect the following data for the first sample plot.

a. Visually estimate the absolute percent cover of bare ground and each plant species in the plot. Bare ground can be represented by either or both of two kinds, fine textured or coarse textured (see datasheet). Since plant species can vertically overlap, their values for absolute percent cover can sum to more that 100% for each plot.

b. Each species observed is classified as (1) native or non-native according to the Jepson Manual (Hickman, 1993); (2) planted or not planted based on site-specific list of planted species; and (3) removed or not removed based on a site-specific list of species that were removed. Planted individuals are not assessed separately from naturally recruited individuals. The net effect of recruitment can be assessed as the difference between the first and subsequent samples.

c. The visual estimates of absolute percent cover greater than 3% are rounded to the nearest 5%. Values ≤ 3% are rounded to the nearest 1%.

All field personnel who are collecting data to compare strata within or among sites must be calibrated to each other. This means that each person independently estimates absolute percent cover for each species in the same calibration plot; that the participating personnel compare their estimates; that they confer with each other regarding any differences greater than 5 percentage points for any species having an absolute percent cover value > 3%; and that they repeat the process on additional calibration plots until no two estimates for the same species in a plot differ by more than 5 percentage points.

d. All data must be recorded on the standard datasheet for this protocol (see attached datasheet).

5. Complete steps 1-5 of the section above titled "*Finalizing the Sample*".

6. Complete all the sampling in the intertidal stratum before proceeding to an upland stratum. Complete the sampling in one upland stratum before proceeding to another.

7. To sample an upland stratum, go to the distance along the tape at the backshore that corresponds to the first plot selected into the sample draw for that stratum. Extend a second tape uphill and perpendicular to the backshore to the middle of the upland stratum being sampled. Carefully center the sample frame on the end of the second tape, such that the downhill edge of the frame is parallel to the backshore (Figure 5). Collect data from the plots according to Steps 4 and 5 immediately above.
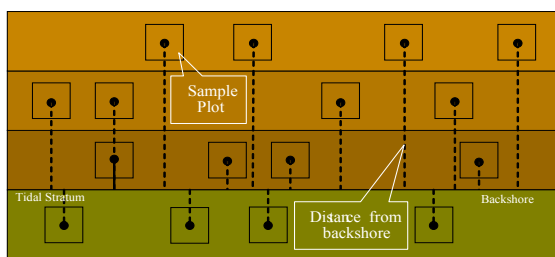
Figure 5: Schematic diagram of arrangement of sample plots within each stratum at randomly selected distances along the backshore. The distances are randomly selected for each stratum

Sample Timeframe and Sample Period

The sample timeframe is the time of day and time of year when the field data should be collected. All data should be collected after most of the perennial vegetation has added its annual biomass and before annual vegetation has senesced. The data for the intertidal stratum should be collected at a time of day when the stratum is not inundated with water.

The sample period is the portion of the timeframe when data are actually collected. All data for all strata and sites should be collected during the shortest period possible to maximize their comparability.

For the purpose of assessing the effects of management activities, baseline data should be collected before the activities ensue and annually thereafter. The length of the monitoring effort (i.e., the number of years of monitoring) will vary from project to project.

Basic Field Equipment

- ✓ 100m transect tape to lay along the backshore
- ✓ Survey level for sighting the backshore
- ✓ 25m transect tape for locating sample plot centers perpendicular to the backshore
- ✓ $1m^2$ plot frame divided into 100 equal-size cells (10cm to a side)
- ✓ GPS unit
- ✓ Camera
- ✓ PVC markers and hammer
- ✓ Plant press for collecting reference specimens
- ✓ Data sheets

Data Analysis and Interpretation

The species-area curves used to determine the final sample size will be developed in the field, as the data are being collected. A datasheet for this purpose is attached. Whether a species is native or alien will be determined automatically by the database. The database will also automatically identify the dominant species for each stratum of each site, and for each site as a whole, using the modified version the USACE 50/20 rule.

The power analyses needed to assess the adequacy of the final sample size for determining the differences in species abundance between strata or between sites, given the sample size determined from species-area curves, will be conducted after the data are collected.

Since ecotone width can vary among sites, the number of strata might also vary among sites. Also, since the number of plots needed to assess species richness can vary among strata, the number of plots might vary among strata as well as among sites. These differences in sample design do not influence the comparison of one stratum to another within a site, one stratum or site to itself over time, or the comparison of sites that have the same number of strata. But, they do limit comparisons between sites having different numbers of strata, as explained below.

Consider the situation illustrated by Figure 6. Site A and Site B are adjacent to each other and therefore subject to the same tidal regime. The intertidal strata of the two sites are comparable because they represent the same marsh plain. However, since the upland strata are delimited by equally subdividing the upland portion of the ecotone at each site, it is possible for two adjacent sites of different width to have different numbers of upland strata. In this example, Site A is wide enough for three upland strata (labeled 1-3), whereas Site B is only wide enough for two uplands strata (labeled 1 and 2). Because of the difference in slope between the two sites, all of stratum A2 is lower in elevation than stratum B2. This means that Stratum A2 is inundated more frequently than stratum B2. The plant communities of these two strata are therefore likely to be different. In general, sites with different numbers of upland strata should be compared based on their intertidal strata, and based on the overall condition for all upland strata combined, and not on the basis of individual upland strata. This limitation could be eliminated by delimiting the upland strata based on the frequency of tidal inundation, but the required tidal data do not exist for most sites.
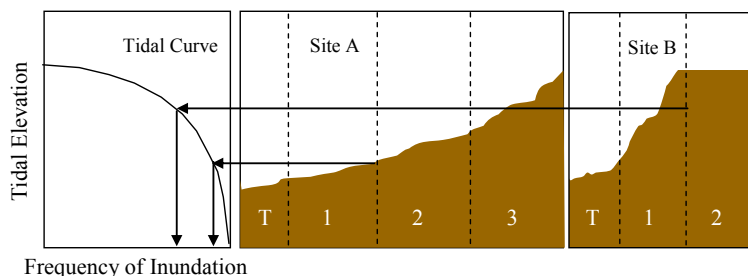
Figure 6: Schematic diagram of two hypothetical adjacent sites A and B having different numbers of upland strata that represent different inundation regimes. For example, stratum A2 is lower than stratum B2, and is therefore inundated more frequently.

The data generated by this protocol are categorical. That is, they describe conditions within discrete portions of the ecotone, called sample strata. Based on this protocol, each stratum will have a population of data points with a mean and variance that can be used to statistically test for differences between strata at a site, between different time periods for the same stratum at a site, and between comparable strata of different sites. The appropriate statistical tests for these comparisons will be analyses of variance. Relationships between two or more parameters measured at the same plots can be explored using regression analyses (Figure 6).

Each stratum and site will be analyzed in terms of species richness, the frequency of occurrence and absolute percent cover of each dominant plant species and bare ground, and absolute percent cover of non-native dominant species. The results can be used to assess how the distribution and abundance of plant species indicative of the tidal marsh plain vary among sites, and how the plant community varies with distance above adjoining marshland or tidal flat. The degree to which these patterns correlate to site-specific factors, including ecotone width, salinity regime, restoration design, and management practices, can also be assessed. Such assessments can help determine which plant species are best suited for each elevation stratum within and among sites, and to determine which restoration and management practices are more effective.

Figure 7: Example plots of hypothetical results showing (A) comparison of two parameters at one site; (B) comparison of two sites based on one cover parameter; (C) changes over time for one parameter at one site; and (D) correlation between two dominant plant species at one or more sites.

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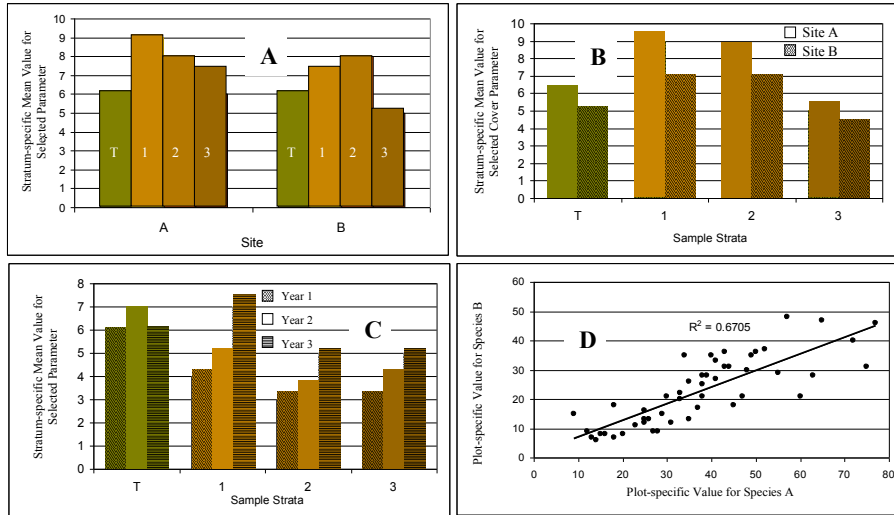Baye, P.R. 2007. Selected tidal marsh plant species of the San Francisco Estuary a field guide. Prepared for the San Francisco Estuary Invasive Spartina Project, California Coastal Conservancy, Oakland CA.

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Project Name: _____   **Begin UTM:** _____   **Field Staff:** _____

Sample Site Name: _____ _____   **End UTM:** _____   _____

Sample Site Code: _____   **Begin UTM:** _____   _____

Date: _____   **End UTM:** _____   _____

Start Time: _____   **End Time:** _____   _____

Stratum	Sample Plot	Species Code	Absolute Percent Cover	Comments

Biotic Cover Code:
Plants: first three letters of genus and first letter of species (e.g. SALV for *Salicornia virginica*).

Sessile animals (shellfish etc): SA

Abiotic Cover Code:
Fine Bare Ground (FBG): diameter of most particles ≤ 2mm

Coarse Bare Ground (CBG): diameter of most particles > 2mm

Strata Codes:
From low to high elevation: Tidal (T), Upland A (UA), Upland B (UB), Upland C (UC); there are normally three upland strata (UA-UC)

Sample Plot Code:
3 letter acronym of site name, first letter of Strata code, and plot number (e.g. MLKT1, MKLT4, MLKUA3, MLKUA1, MLKUC3, etc)

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Intertidal – Upland Ecotone Plant Community Species Area Curve

Project Name: _____   **Sample Site Name:** _____   **Sample Site Code:** _____

Sample Date: _____   **Stratum Code:** _____

Cumulative Number of New Plant Species (y-axis, labeled 1–30)

Consecutive Sample Plots Starting with the First Selected into the Sample Draw (x-axis, labeled 1–30)