Data Collection Protocol
Distribution, Abundance, and Treatment
Of Non-indigenous Species of Cordgrass
In the San Francisco Estuary

Part A: Local Conditions
Part B: Regional Conditions

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Acknowledgements

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Statement of Need

Non-indigenous invasive species (NIS) of cordgrass, genus *Spartina*, are spreading in the San Francisco Estuary. The invasions might negatively impact many aspects of the estuarine ecosystem, including navigation, flood control, and native fish and wildlife. These guidelines will help develop basic information about the status of the invasions and the efficacy of the treatments. The intended audience for this information is the regional community of environmental managers, scientists, and concerned citizens. It is expected that these guidelines will be used by the Invasive Spartina Project (ISP) that is being organized to control NIS *Spartina* invasions in the San Francisco Estuary.

Purpose

There are many important questions about the nature of the invasions and treatment effects that might be addressed by a monitoring program. But a few fundamental questions underlie all others. The purpose of these guidelines is to present the methods for collecting the kinds of field data that are needed to answer the following kinds of questions.

> Policy Questions
>> How is successful control defined?
>
> Management Questions
>> What areas should be treated, by what methods, in what priority?
>
> Factual Questions
>> What is the regional distribution and abundance of the target species?
>>
>> How effective are different treatment approaches under different conditions?
>>
>> What are the costs of different types of treatment?
>
> Forecasts
>> What might be the future distribution of the target species based upon their response to treatments?

Geographic Scope and Spatial Scale

NIS *Spartina* should be monitored at three scales: Individual treatment sites, multiple treatment sites, and the Estuary as a whole. The temporal frequency of monitoring will vary between indicators.

?? *Individual treatment sites*. Individual sites are subject to no more than one treatment type for a specified period of time. The size and shape of treatment sites should be conducive to consistent and comprehensive treatment over time. A site should be obvious; it might be delimited by clearly marked property lines, levees, or other engineered structures.

?? *Multiple sites*. Different sites might be compared based on treatment type (e.g., sites of chemical spraying compared to sites of physical control), environmental

characteristics (e.g., saline sites versus brackish sites, or South Bay sites versus Central Bay sites) to assess the effects of these factors on treatment efficacy. A site might be compared with itself over time and with other sites of the same and different kinds.

?? *Estuarine ecosystem.* The entire potential geographic range of the NIS *Spartina* species within the San Francisco Estuary should occasionally be surveyed to determine if the invasions are spreading beyond the geographic limits of the more intensive monitoring and treatment sites.

Guidelines to Monitor Treatment Sites

Selection of Monitoring Sites

A monitoring site is a treatment site that is selected for monitoring the efficacy of treatment efforts. Not all treatment sites will be monitored. Site selection requires an understanding of site logistics and local ecological and social sensitivities, as well as the relative importance of different sites in the context of the overall invasion. To the extent practicable, the selection of monitoring sites should be coordinated with other wetlands monitoring efforts. Monitoring sites will be selected by the regionally coordinated Invasive Spartina Project (ISP), based upon these concerns plus the availability of adequate funding for monitoring.

For the purposes of monitoring, a site is too large if it cannot be monitored within the required timeframe. It is too small if it cannot provide the adequate sample size (see Sample Size below), or if it would yield results that are likely to be confounded by off-site events.

In time, as the data record is extended, monitoring results might be used to predict the efficacy of treatment at sites and thus reduce the amount of monitoring that is required. Such predictive capability will not, however, completely eliminate the need to monitor at any site. These guidelines should yield results from many sites that can be used to develop and test predictive models, and thus provide a basis for modifying, and perhaps simplifying, the monitoring program.

Sampling Universe

A sampling universe is defined as the place and time that can be described by the monitoring results. For example, if there is a need to describe conditions of NIS *Spartina* for all the saline tidal marshes in the Estuary during autumn, then NIS *Spartina* must be sampled in autumn throughout the distribution of saline tidal marshes, and the results cannot be applied to other kinds of marshes or to other times without large assumptions that differences between the places or between the times are not significant. Similarly, if there is a need to describe conditions at a particular treatment site, then the sample must be drawn from the site, and the results cannot usually be applied to other sites, although results from similar sites might be combined (see Geographic Scope and Spatial Scale above).

For the purpose of monitoring individual sites, there are two kinds of samples. The *treatment sample* is drawn from the places within a site where NIS *Spartina* is

actually treated. These places constitute the *treatment universe*. The *untreated sample[1]* is drawn from places within a site or at comparable sites that are not treated. These places constitute the *untreated universe*. Treatment samples are needed to describe the conditions of treated *Spartina* or its habitat. Untreated samples are needed to describe background or ambient conditions of untreated *Spartina* or its habitat. If the treatment samples and untreated samples are taken at comparable places and times, then they can be used to evaluate the efficacy of the treatment.

Definition of Treatment Success

The treatment of NIS *Spartina* is complicated by a variety of ecological and social factors. The most complicating ecological factor is hybridization between the invasive *Spartina alterniflora* and the native *Spartina foliosa*. These hybrids may pose greater ecological and economic threats than the original invaders, while also reducing the ability of field personnel to distinguish the invaders from the native species. Uncertain identification of the target species can greatly reduce the efficacy of treatments.

According to the ISP, the initial definition of success for the system as a whole is no net increase in acres of NIS *Spartina* as measured against the 2001 base line. But hybridization complicates the meaning of treatment success. Although the biology of *S. alterniflora* and *S. foliosa* favors the traits of the invader (Anttila and Daehler 1997, Anttila et al 1998, Daehler et al 1999), aggressive treatment of obvious *S. alterniflora* may promote local hybrid populations with growth habits more similar to the native species. Successful treatment may mean dominance by a hybrid population that is an ecological and geomorphic analogue to the native species. Monitoring must therefore use indicators of progress or regress relative to evolving definitions of treatment success.

Indicators and Methods of Data Collection

Indicators of field conditions of NIS *Spartina* have been selected to address the fundamental management questions (see Purpose above). Standard methods for these indicators are required to contrast and compare the efficacy of treatment for different types of treatment and different treatment sites.

Indicators of Spatial Distribution

The invasion by NIS *Spartina* may extend the vertical range of emergent vascular vegetation within the intertidal zone of the San Francisco Estuary. Invasion of NIS *Spartina* into the upper zone might displace native species that inhabit tidal marshes. Invasion into the lower zone might also decrease the amount of unvegetated tidal flat. These changes in plant species composition and distribution in the intertidal zone could have significant negative impacts on the ecology and economy of the Estuary (WSU

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[1] The terms, "treatment" and "control," have different meanings in the language of experimental design than in the language of managing NIS Spartina. Statisticians regard treatment conditions and control conditions as comparable but not necessarily similar. For Spartina managers, treatment and control mean the same thing. To prevent confusion, the terms "treated" and "untreated" are used here. In terms of statistics, the untreated sample represents control conditions. In terms of management, the untreated sample represents conditions in the absence of control efforts.

1997). The vertical distribution of NIS *Spartina*, its abundance relative to native plant species, and the amount of tidal flat should therefore be monitored at treatment sites.

Vertical Range

The maximum and minimum positions of NIS *Spartina* along the slope of the intertidal zone is a practical indicator of its vertical range. Movement of *NIS Spartina* along this slope would indicate that its vertical range is changing.

Table 1 (beginning on the next page) outlines three approaches to measuring the vertical range of *NIS Spartina* at different costs and benefits. The information content and cost of the approaches depends on the amount of surveying that is conducted to determine elevations. The simplest approach should be the default choice, since it provides the basic data at minimum cost. The more complex approaches might be used at some sites to help explain variations in the vertical range.

Relative Abundance

This is a set of indicators for changes in the abundance of NIS *Spartina* relative to native vegetation. The individual indicators are:

- ?? Number of random sample plots containing NIS *Spartina*;
- ?? Number of random plots containing native *Spartina*;
- ?? Number of random plots containing hybrids;
- ?? Average percent cover of NIS *Spartina*, native *Spartina*, and hybrids per plot;
- ?? Average percent cover of native plant species per plot.

Sampling plots should be randomly selected from a population of possible plots within the treated universe and the untreated universe. The sampling universes should be mapped on geo-rectified, mosaic-ed, CIR or black/white aerial photography, scale 1:6,000, taken at slack low water during a very low tide. The photography should not be older than two growing seasons. A GIS will be used to draw a uniform grid with 5-m nodes across each sampling universe. Each 25-m^2 cell of the two grids will be uniquely coded. The horizontal GPS coordinates of the center point of each cell will be determined as a cell attribute. At least 30 cells will be randomly selected from each sampling universe. Field workers will be provided with a photo map of the selected cells and their GPS coordinates. Data will be collected within one 0.25-m^2 plot at the center of each selected cell. The GPS coordinates of the center of each plot will be noted. Sampling will occur annually near the time of flowering by NIS *Spartina*.

Table 1: Three Alternative Approaches to Measure the Vertical Range of NIS *Spartina* at Treatment Sites

Approach One	Method	Comments
Horizontal Position Relative to the Backshore of the Intertidal Zone. This is the simplest or most basic approach that requires minimal field data and minimal surveying expertise.	1. Backshore and foreshore are defined as uppermost and lowermost boundary of intertidal vegetation. Useful proxies for the backshore include the center lines of levees, upper margin of rip-rap, or any other fixed, permanent, linear features that parallel the shoreline and are clearly visible in orthogonal aerial photography of scale 1:6,000. The same proxies are used over time at any given treatment site. 2. GPS is used to establish ground controls for scaling and geo-rectifying the aerial photography, or the scale is controlled using ground measures of distance between visible landmarks. 3. The maximum and minimum positions of NIS *Spartina* relative to the backshore are measured at shoreline intervals of 100 feet on the scaled aerial photographs within the treated universe and the untreated universe, and noted on the scaled aerial photographs of the treatment site. 5. The distances from the backshore to the minimum and maximum positions of the *NIS Spartina* are measured in meters, and reported as the intertidal range of NIS *Spartina* for the site.	This approach is based on the fact that the intertidal zone slopes downward from the backshore (maximum elevation of estuarine vegetation) to the foreshore (minimum elevation of vegetation). Based on this simple fact, the distance from either shoreline to a patch of NIS *Spartina* can be used as a proxy measure of the tidal elevation of the patch. The center lines of levees and riprap are better than their bayward margins because the centerlines are visible at any tide stage and are more easily identified in aerial photos. This approach yields reasonably accurate and reproducible results without involving more costly and logistically difficult fieldwork. This approach requires no surveys of actual elevation but yields reasonable proxy measures of changes in vertical range and position of NIS *Spartina* within the intertidal zone. This approach requires geo-rectified aerial photography. But such photography is also required as a base map for measuring the spatial extent of local invasions at treatments. This approach yields a photo record of the maximum and minimum distribution of NIS *Spartina* within the intertidal zone of the treatment site.

Table 1 (continued): Three Alternative Approaches to Measure the Vertical Range of NIS *Spartina* at Treatment Sites

Approach Two	Method	Comments
Vertical Range and Position within the Intertidal Zone as Referenced to a Standard Geodetic Datum (NAVD 88) Using GPS. This is a moderately complex approach requiring a moderate amount of field data and surveying expertise, especially for GPS.	1. The National Vertical Datum of 1988 (NAVD 88) is the standard reference plane for determining land surface elevations. Local elevations relative to NAVD can be determined to within a few tenths of a foot using survey-grade GPS. 2. Survey-grade GPS is used to determine the elevations of the three lowermost and uppermost margins of NIS within the treated universe and the untreated universe. 3. The survey results from step 2 above are used to report the vertical range and position of NIS *Spartina* in meters relative to NAVD 88, at the treatment site.	GPS provides rapid estimates of elevation relative to a standard vertical datum that can be used to compare changes in vertical range within and between treatment sites. GPS estimates of elevation are rather coarse relative to the sensitivities of intertidal plants to variations in topography. GPS may not be accurate enough to yield information about elevation thresholds of NIS *Spartina* or rates of its vertical extension over short periods of time. This approach requires fieldwork that because of its logistical difficulty in many sites cannot be used along transects to collect as much data as Approach One. If the geodetic elevations of local tidal benchmarks relative to NAVD 88 have been determined, then the tidal elevations of the NIS *Spartina* can be inferred from the GPS elevation values. These tidal elevations will have the error of both GPS and of the tidal datum of the benchmarks, however, and might therefore be very coarse relative to the sensitivities of intertidal plants to changes in actual tidal elevation. This approach does not require aerial photography, but therefore does not provide a photo record of site conditions.

Table 1 (continued): Three Alternative Approaches to Measure the Vertical Range of NIS *Spartina* at Treatment Sites

Approach Three	Method	Comments
Vertical Range and Position within the Intertidal Zone as Referenced to a Local Tidal Datum (MHHW) using site-specific tidal stage data. This is a the most complex approach requiring the most field data and surveying expertise.	1.The Mean Higher High Water datum (MHHW) can be estimated for a treatment site based on site-specific or site-relevant records of high tides. If accurate tidal benchmarks are not available, then they must be established, following steps 2-4 below. The results will be tidal elevations of *Spartina* referenced to the local, or site-specific MHHW datum. 2. Establish one or more staff gauges at the treatment site. 3. For each staff gauge, record the maximum height of five or more spring series high tides. Record the maximum tidal elevations of the same high tides at a nearby control staff gauge that is referenced to an accurate tidal benchmark. 4. Regress the stage heights from the site on the stage elevations from the control station to estimate tidal elevation of the staff gauges at the site. 5.Conduct a survey of land surface elevations in meters relative to the local tidal datum of the three lowermost and uppermost margins of NIS *Spartina* within the treated universe and the untreated universe.	Careful reference to a tidal datum can yield information about possible correlation between field conditions of NIS *Spartina* and presumably important hydrological characteristics of its habitat, including the depth, duration, frequency, and timing of estuarine inundation. Although monitoring of these characteristics is not critical for measuring a change in vertical range of NIS *Spartina* or for measuring the efficacy of treatment, it might be critical for understanding the nature of the invasion and for explaining variations in treatment efficacy. This approach requires fieldwork that because of its logistical difficulty in many sites cannot be used along transects to collect as much data as Approach One. Local determination of tidal datums requires on-site collection of tidal stage data, and the accuracy of the datum is a function of the length of the data record. Short records of a few days may be adequate to estimate a high tide datum at any given gauging station within a site, but a number of stations might be required at large sites to adequately describe the spatial variability of the datum.

Figure 1 Captions (see page 9)

Figure 1 (next page) illustrates the basic random sampling scheme recommended for selecting sampling plots.

Figure 1A indicates that sampling sites can be located anywhere in the San Francisco Estuary.

Figure 1B shows that the boundaries of a sampling site may not coincide with the boundaries of the aerial photography used as a base map for sampling. The yellow rectangle represents the treated universe.

Figure 1C depicts the actual spatial distributions of native *Spartina*, NIS *Spartina*, and hybrids within the treated universe. These distributions would change over time, due to on-site treatment and natural processes. One purpose of the sample is to describe these changes based on the spatial distribution indicators.

Figure 1D shows a random array of cells selected from a uniform sampling grid for the treated universe. One sample plot would be located in each selected cell. Subsequent samples from this site would require a new random cell array. The GPS coordinates of each selected cell should be saved as a set of cell addresses for each sampling period, such that cells can be revisited if necessary. For example, cells might be randomly revisited to test for re-generation or re-colonization of NIS *Spartina*.

Figure 1. Sampling Scheme for *Spartina* Monitoring

San Francisco Estuary

A

A control site

B

25m

mudflat

marsh

bay

C

mudflat

bay

native
NIS
hybrids

Georectified image of *Spartina* distribution

D

32 random sample plots for marsh and mudflat
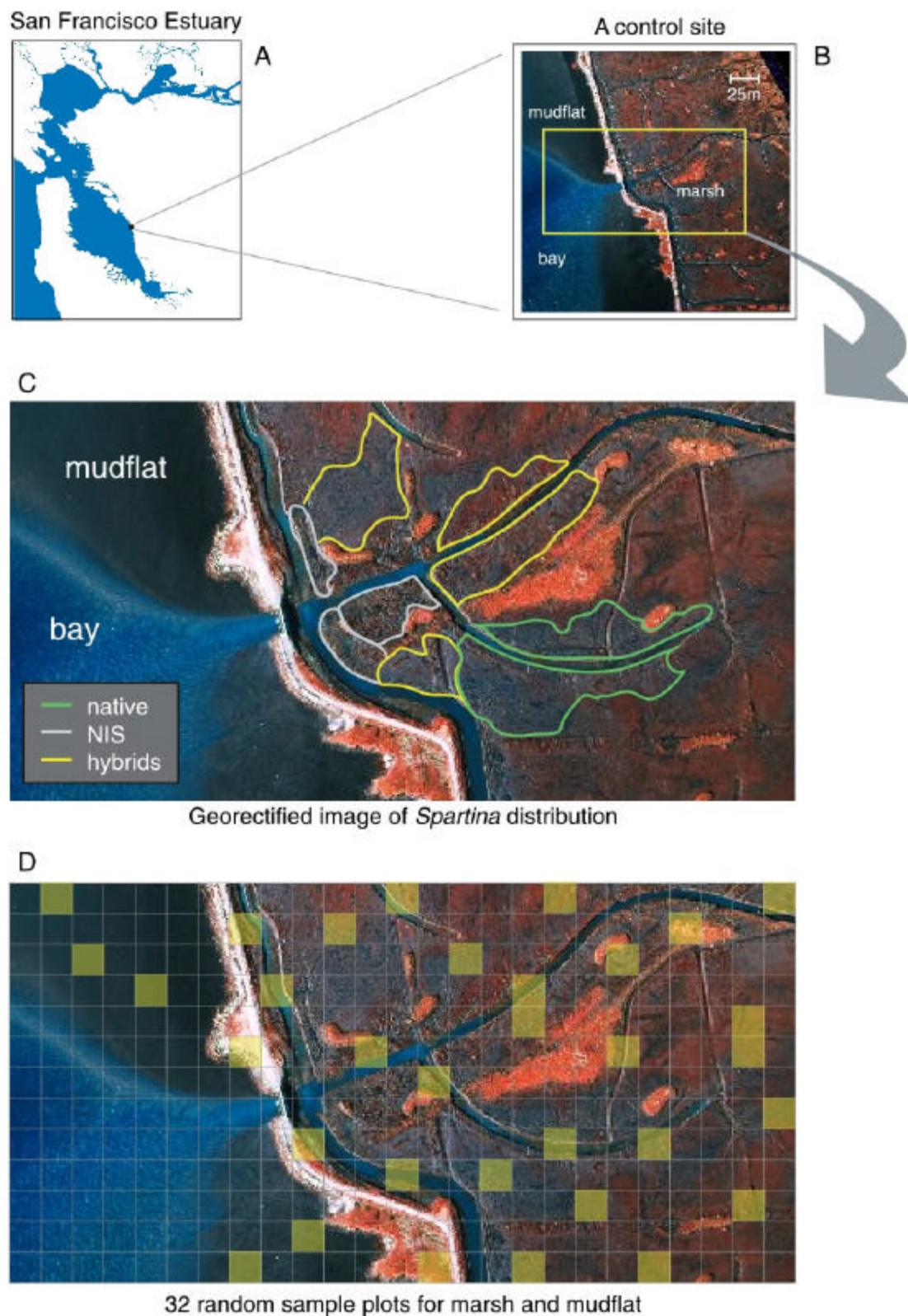
Percent Cover

Estimates of percent cover will fall into 5% classes (i.e., 0-5%, 6-10%, 11-15%, and so forth), based on visual inspection from directly above each plot. The vertical stratification or layering of plant species within the plot will be ignored. Field personnel should routinely use test plots to standardize their taxonomic treatments and to calibrate their visual estimates of percent cover.

Amount of Tidal Flat

The amount of tidal flat will be measured as square meters of unvegetated substrate that is visible on geo-rectified, mosaic-ed, CIR or Black and White aerial photography, scale 1:6,000, taken at slack low water during a minus tide at the peak of the *Spartina* growing season for each treatment site. The tidal elevation of the slack low water will be estimated based on the timing of the photos relative to the tidal record, as provided by NOAA for its nearest Primary Tide Station. Photos should be

Figure 2. A 0.25 – m^2 sample frame made of 1/2–in schedule-A PVC pipe

taken annually. Over time, a series of photos will exist for each site that depict the lowermost edge of exposed tidal flat during different water levels of known elevation. For each site, a compilation of these photos can be used to estimate the position of the Mean Lower Low Water (MLLW) or Mean Low Water (MLW) tidal datum contour. All tidal flat measurements should eventually be standardized using the low tidal datum contour as the lowermost margin of tidal flat.

Indicators of Vigor

There may be sub-lethal treatment effects that are indicated by reductions in the stature or vigor of the treated NIS *Spartina*. Stem density and average maximum stem length are the two most basic field indicators of plant stature and vigor. It is expected that the vegetative reproduction capability of the target species and the difficulty of its treatment are positively related to these indicators. Stem density also affects the ability of *Spartina* to attenuate waves, and to filter and entrap suspended sediment (Gray et al. 1997, Josselyn et al. 1993). Average maximum stem height might also relate to the ability of *Spartina* to survive the more frequent and prolonged tidal inundation regimes of the lower intertidal zone.

Figure 3. Measuring stem height
from ground to base of flowers.
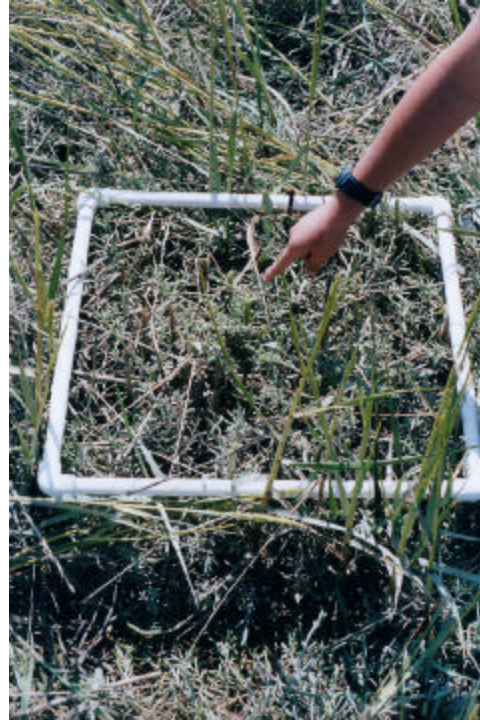
Figure 4. Counting cut stems as a
measure of stem density.

Maximum Stem Height

Within each of the 0.25-m^2 sample plots of the selected grid cells of the treated universe and the untreated universe (see discussion of Relative Abundance indicator on page 4 and sampling scheme illustration on page 8 above), the total length or height of the tallest or longest stems of NIS *Spartina* or hybrids are measured to the nearest cm. Ten of the longest stems in each plot should be selected based on visual inspection of the sampling plot. Since stem height is related to stem girth, the girth of stems at a height of about 10 cm above the ground can be used to help select the tallest stems. Measurements of stem height or length should be made from the ground surface to the stem tip or base of the infloresence, not including the flowers. If necessary, stems can be straightened by hand to facilitate accurate measurements. Field personnel should routinely use test plots to calibrate their visual selection of long stems. Stem height should be measured annually, near the time of *Spartina* flowering.

Stem Density

Within each of the 0.25-m^2 sample plots of the selected grid cells of the treated universe and the untreated universe (see discussion of Relative Abundance indicator on page 4 and sampling scheme illustration on page 8 above), the total number of stems of *Spartina* should be counted. To facilitate the count, all the stems within the study plot should be cut squarely at a height of about 10 cm above the ground surface. The cut stems should be left within the treatment site. Stem density should be measured annually, near the time of *Spartina* flowering.

Genetic Indicators

Accurate classification of the monitoring data among the NIS *Spartina*, hybrids, and native species is essential to monitor the invasion and the efficacy of treatment. Since hybridization produces phenotypic intergrades, genetic testing is required to certify the taxonomic identification.

Genotype

Tissue samples will be taken for each taxonomically uncertain patch of *Spartina* that is measured for any indicator. The sample unit will consist of 10 to 20 cm^2 of healthy leaf tissue. A permanent marker will be used to directly label each sample unit with the sample unit code. For example, it must be clear which transect position or sample plot and date is represented by each tissue sample. Each sample unit should be placed in a separate plastic bag, sealed, and sent to a

Figure 5. Taking a tissue sample.

reputable laboratory for genetic analysis. Using Randomly Amplified Polymorphic DNA (RAPDs), five primers with previously determined species-specific bands for *S. alterniflora* are used to confirm samples as native *S. foliosa* (zero bands), hybrid (any intermediate number of bands) or non-native *S. alterniflora* (5 positive bands) (Ayres *et al.*, 1999). Samples should not be subjected to high heat, prolonged direct sun light, or freezing. Samples can be refrigerated for a few days before laboratory testing.

Sample Size

The sample size required to detect a given level of treatment effect with a desired level of confidence can be estimated based on the statistical variance of the indicator. But at this initial stage of the NIS *Spartina* monitoring effort, the data for indicators are not adequate to describe their statistical variability. Therefore, a starting sample size has been selected based on assumptions about the statistical characteristics of the indicators and the levels of treatment effects that need to be detected. As the database for the indicators grows, sample sizes can be computed for threshold values of treatment effects that trigger management decisions with desired levels of confidence. The revised sample size might differ among the indicators.

For initial sampling efforts, the choice of sample size is as much a function of budgetary considerations as it is statistical considerations. For the purposes of standard parametric statistical analyses, samples of at least 30 units are preferred over smaller samples sizes. But the optimal sample size will vary between indicators based upon their statistical variances and sampling costs.

The initial sample sizes that have been recommended in these guidelines are based on a number of assumptions.

?? The sampling plan is designed to determine what is happening, not why. The monitoring data will describe spatial and temporal patterns of distribution of *Spartina* relative to treatments, rather than the causes of the patterns that are observed. Spatial or temporal correlation between changes in *Spartina* distribution and treatment will be used to infer treatment effects. Formal proof of treatment effects requires experimental manipulation of treatments to test for cause and effect relationships between treatments and the target species. Such experimentation is not being planned as part of monitoring at this time.

?? Only the most fundamental indicators that are expected to relate directly to the response of *Spartina* to treatment will be used at every treatment site. However, the efficacy of treatment may be significantly influenced by tidal hydrology, as indicated by the vertical range of *Spartina* in the intertidal zone. Vertical range will therefore be measured for at least some treatment sites to infer how it relates to the efficacy of treatment.

?? Sample size will be adjusted for each indicator after its statistical variance has been calculated. This means that the first sample must be used to estimate the sample size for subsequent samples. In this context, the first sample is a pilot study.

?? Treatment will be halted when and where it is successful. Treatment success will be defined by natural resource managers using the monitoring results. The managers will need to feel confident that the monitoring data provide an adequate basis for their decisions. But the information content of the data will increase as the monitoring progresses. This means that the definition of success may evolve.

?? The monitoring results will be analyzed using standard parametric statistical tests. Most of the tests will be uni-variate. Multi-variate exploration for correlation will be minimized.

?? Treatment samples and control samples should be equal size for any indicator, but sample sizes can differ between indicators.

?? Field personnel will be able to minimize sample error and bias by applying expert techniques and abundant field experience. If necessary, experts can train other field personnel to conduct the sampling, but oversight by trained professionals with abundant experience in sampling intertidal vegetation will be critically important.

?? The initial sampling effort will have adequate funding to follow the standard recommendation of at least 30 sample units.

List of Data Fields

The data sheets or the GPS data dictionary should be structured to record the following categories of data, based on the recommended indicators. Data from these categories will be entered into a database for the calculation of summary statistics and for analyses. Some of the data will result from post-sampling laboratory tests and aerial photo interpretation through a GIS.

Universal Categories

    Treatment Site
    Date
    Field Personnel
    Treatment Method

Indicators of Spatial Distribution

    Vertical Range (there are three alternative approaches – see text)
        Approach No. One
            Maximum Distance to Backshore (m)
            Minimum Distance to Backshore (m)
        Approach No. Two
            Minimum Elevation Relative to NAVD 88 (m)
            Maximum Elevation Relative to NAVD 88 (m)
        Approach No. Three
            Minimum Elevation Relative to Local MHHW (m)
            Maximum Elevation Relative to Local MHHW (m)

    Relative Abundance
        Grid Cell Code
        Sample Plot Code
        Percent Cover by Species in 5% intervals

    Amount of Tidal Flat
        Number of m^2 for the Site Overall

Indicators of Vigor

    Maximum Stem Height or Stem Length
        10 measurements (cm) per plot
    Stem Density
        Total Number of Stems per Plot

Genetic Indicator or Species

    Genotype
        Genotype Code (for uncertain NIS Spartina) or species code for Each Measured Patch of *Spartina* (at each plot and place of distance or elevation measurement)

Analytical Procedures

The data will be summarized as the mean and standard deviation of each indicator for the treatment samples and the control samples for each treatment site and sampling date. The analysis will include comparisons between treated and untreated populations (uni-variate parametric tests of two means); comparisons between sites and between treatment types (uni-variate parametric tests of multiple means – this requires knowing what treatment types are used on which sample plots); treatment effects as a function of elevation or position along the intertidal gradient (simple regression); correlation among more than two species and indicators (co-variance analysis and PC analysis).

Example Presentation of Results

Figures 6A – 6D present hypothetical monitoring results to show how they might be used to assess the efficacy of treatment at one site. No single indicator provides all the information necessary for the assessment. The challenge is to use a variety of basic indicators, each of which provides part of the information that is most needed. Training and experience are required to interpret the findings. In this set of hypothetical examples, annual data for amount of tidal flat, percent of plots with NIS *Spartina*, relative abundance of *Spartina*, and its stem density are presented for a five-year period.

Taken together, these data suggest that the amount of NIS *Spartina* increased at the treatment site during years 1-3 by colonizing the tidal marsh and tidal flats. During years two and three, *Spartina* conditions on the site were indicative of a large NIS *Spartina* infestation. Ongoing, selective treatment of NIS *Spartina* correlates to an increase in the abundance of hybrids that apparently have a similar vertical range and stem density as the native *Spartina*. After five years, the overall abundance of *Spartina*, its vertical range and its growth habit resemble the pre-treatment conditions. In terms of these indicators, the treatment might be judged successful at this site.

Figure 6A shows that the amount of tidal flat at the treatment site decreased for the first three years of the five-year record. Thereafter, the amount of tidal flat increased to its pre-treatment level. In the control universe, the amount of tidal flat continued to decrease.
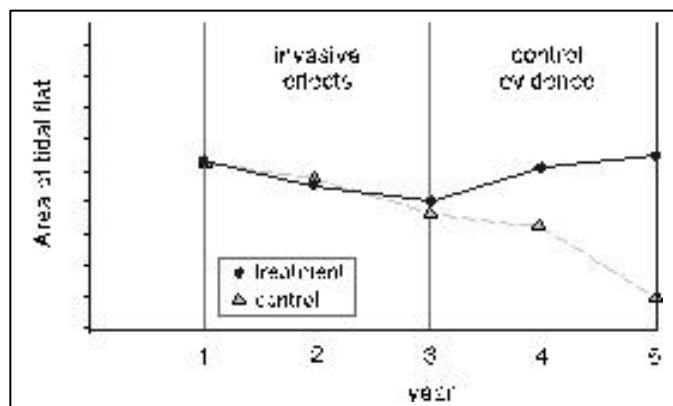
Figure 6A. Changes in amount of tidal flat

Figure 6B shows that the abundance of NIS *Spartina* increased at the treatment site between the second and third years, and then decreased. The abundance of native *Spartina* also decreased. But abundance of the hybrids increased.
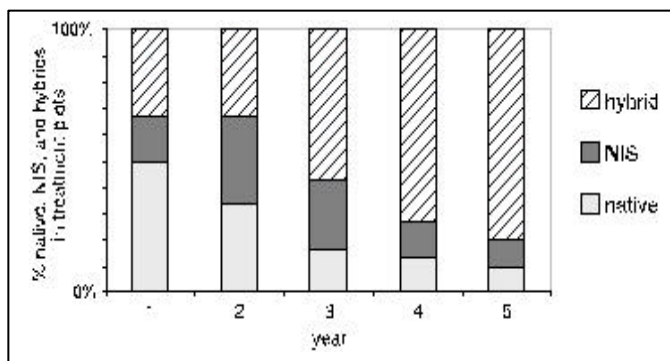
Figure 6B. Relative abundance of Spartina Spp.

Figure 6C shows that, at the treatment site, the overall abundance of *Spartina* increased from years 1-3 and then decreased to pre-treatment levels. In the control universe, the overall abundance of *Spartina* continued to increase.
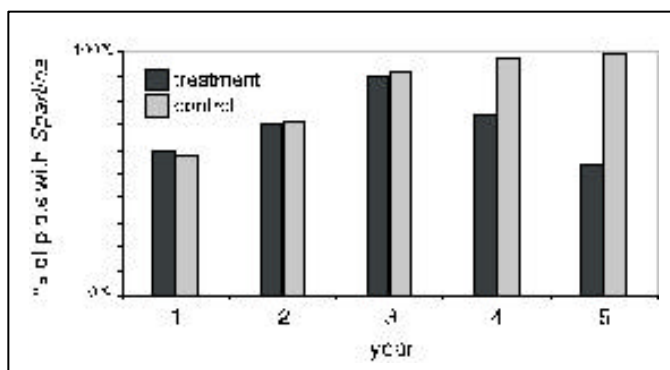
Figure 6C. Changes in Spartina overall abundance

Figure 6D shows that, at the treatment site, stem density of *Spartina* peaked during year three, and then decreased to pre-treatment levels. But in the control universe, stem density of *Spartina* continued to increase.
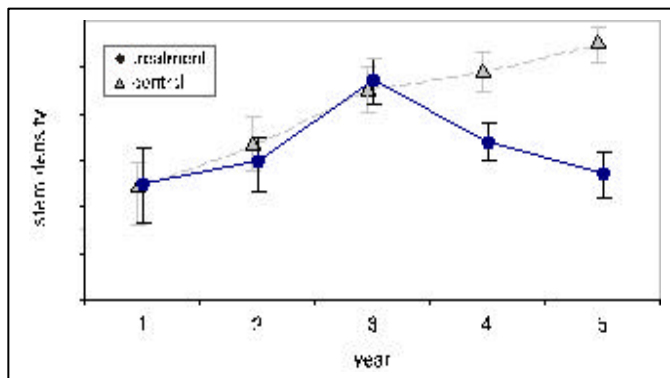
Figure 6D. Changes in stem density

Evaluation of Monitoring Guidelines

These guidelines have been developed based on recent field exercises. It is expected, however, that the guidelines will need to be revised as they are implemented to reflect new scientific understanding and changes in the kinds of information that are needed. The first year or two of efforts to monitor treatment sites should therefore be used as a "testing period" for the basic monitoring approach, including an assessment of the time and resource requirements for continued implementation of the monitoring plan. The Technical Advisory Committee of the San Francisco Estuary Invasive *Spartina* Project (ISP) or a comparable review group will need to evaluate the guidelines during this test period.

Reporting of Monitoring Results

The ISP will present and summarize the monitoring data, analyses, results and provide recommendations regarding further treatment of NIS *Spartina* in an Annual Monitoring Report. The annual report will be made available to all interested parties and on the Internet.

Part B: Regional Distribution and Abundance

Introduction

These guidelines describes a method for mapping the regional distribution and abundance of NIS *Spartina* in the San Francisco Estuary; *S. alterniflora, S. foliosa x S. alterniflora hybrids, S. densiflora, S. patens and S. anglica* The guidelines are based on field work conducted in 2000 and 2001. The ability to monitor regional changes in *Spartina* populations will play a critical role in efforts to manage the invasions.

Summary of 2000-2001 Mapping

Previous efforts to map *Spartina* invasions were reviewed in the context of the particular conditions of the San Francisco Estuary, the needs of wetlands managers in this region, and the budget for mapping. It was decided that the regional distribution of NIS *Spartina* in the Estuary should be mapped through fieldwork with GPS and existing imaging, and, for three selected local sites, the use of GPS with high-resolution aerial photography should be tested.

The use of remote sensing tools to identify patches of vegetation based on pixel color has been attempted by others. These research efforts have thus far illustrated the expected difficulty in distinguishing hybrids from native *Spartina foliosa* or the NIS *Spartina* species. Research is planned to continue to test the ability to remotely sense these species and their hybrids.

In this study, fieldwork made use of GPS units, topographic maps, and aerial photography. Tissue samples were collected for the purpose of obtaining positive identification via DNA analysis. All data collected were digitized, geo-rectified, organized in a database and imported into ArcView GIS software for display, manipulation and summary calculations.

Figure 1. Aerial Photo Coverage 2001

High-resolution Aerial Photography

Three areas in the Estuary were selected for high-resolution (1:6000) color infra-red (CIR) orthogonal aerial photography (Figure 1). This part of the project was intended to determine the feasibility of using aerial photography in mapping *Spartina*. The sites were flown in September 2000. Percent cover for various marshes were determined based on these photos and then confirmed through ground-truthing. Generally, this choice of scale and time of year for photo flights appear to be optimal for mapping and monitoring NIS *Spartina*. Evaluation of the photography is ongoing.
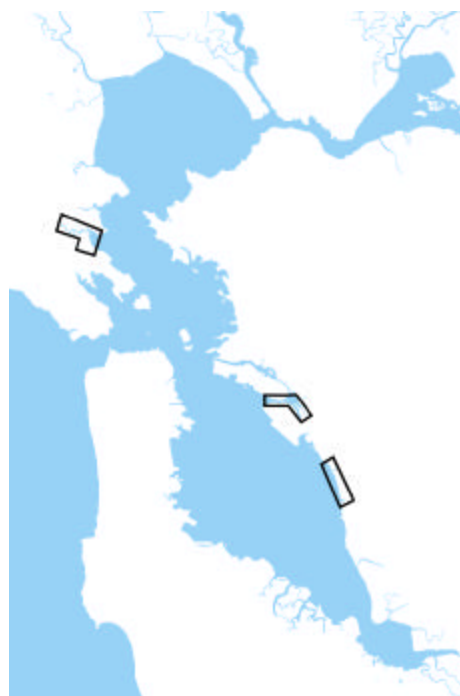
Methods for Known Areas of Invasion

Mapping from High-resolution Aerial Photography

The benefits of using aerial photographic images include detailed, accurate mapping; a permanent visual record; and a reduction in field labor. Aerial photographs (scale 1:6000 or larger) should be taken of as much of the region to be mapped as possible. For the purpose of regional mapping, the best season for photography is late summer/early fall, when the photographic signature of vigorous *Spartina* alterniflora may be distinguishable from *Spartina foliosa* that is entering senescence. The seasonal timing of the aerial photography should be kept consistent from year to year. Photos should be taken at low tide to capture *Spartina* clones growing in the lower tidal zone.

The aerial photos should be scanned (1200 dpi) and geo-referenced. Probable patches of *Spartina* spp. that are apparent in the photos should be field-checked (and DNA samples taken) to verify their taxonomic identity. When the fieldwork establishes sufficient confidence in the interpretation of the photos, *Spartina* patches are mapped directly from the scanned photos by tracing on-screen (a technique known as "heads up" digitizing), using ArcView or a comparable spatial analysis program. Photos are also used in conjunction with field work to more accurately estimate the percent cover of NIS *Spartina* within a defined area.

GPS Fieldwork and Representing *Spartina* in the Mapping Database

Field biologists should use hand-held GPS units with data collection capability to map *Spartina* populations. The Trimble GeoExplorer 3 was chosen for the 2000–2001 field season due to its portability, real-time navigation capabilities, and acceptable degree of accuracy for the project's purposes (1-5 m precision after differential correction).

Spartina is represented in the mapping database as one of three features: a point, line, or polygon (area). These three features form the basis of the mapping system of the GPS units and spatial analysis software. A primary goal of mapping is to record the net acreage of invasive *Spartina*. Therefore, points are given diameters and lines are given widths to represent the area covered by *Spartina*. Ancillary data are entered into the GPS unit as the position of each feature is being recorded. A data dictionary, providing the full structure of a mapping database and notes on mapping protocol, is found in Appendix 1.

Figure 2. Mapping *Spartina* as a point feature

Points

A point feature is typically used to represent single *Spartina* clones, small groups of clones, and larger continuous patches where lack of access prevents walking the perimeter of the patch and representing it as a polygon. When represented by a point, the location of the *Spartina* should be recorded by collecting a GPS position while holding the unit over or immediately adjacent to the *Spartina* (see Figure 2 above). The average diameter of the patch is then entered into the GPS unit, to later be used to calculate area of the patch. Whenever possible, GPS data points should be gathered as close to the center of a clone as possible. If a clone or cluster of clones is not accessible, it is possible to offset the point to the approximate location of the *Spartina* (see "Offsets," below, for more information). "Solitary" clones (roughly defined as an absence of other clones within 50-100 m) are not usually mapped.

Lines

When a patch of *Spartina* is linear in shape, with a consistent width over a length of roughly 10 m or more, such as might be the case along a uniform stretch of shoreline, slough or flood control channel, a line is typically used to represent the patch. In this case, the GPS unit is moved along the length of the patch while continuously (every 5 seconds) collecting positions, thus defining the line. The average width of the patch is then entered into the GPS unit, to later be used to calculate area of the linear patch. The line feature may also be used to delineate a partial perimeter of a polygon, where all sides are not accessible. Using handwritten notes, the surveyor can indicate how this line feature should be hand-digitized on-screen to complete the polygon shape.

Areas

If a large area (typically 30 m or more in diameter) of continuous *Spartina* or areas containing numerous clones are encountered, and if they have fully accessible perimeters, they are typically mapped using a polygon, rather than a point or a line. In critical areas, polygons can also be used to outline the shape of a particular clone to track spread over time, and to calculate a more exact area of coverage. To establish the polygon, the GPS unit is carried along the perimeter of the patch to continuously collect data on position.

Percent Cover

The percent cover of *Spartina* can vary between areas mapped as lines or polygons. Percent cover should therefore be visually estimated for each polygon and line. Point features, however, are only intended to represent areas of 100% cover of *Spartina*. Estimates of percent cover will fall into one of seven classes: 0, 0-1 (seedlings), 1-10, 10-30, 30-60, 60-90, and 90-100 (see % cover feature of data dictionary in Appendix 1). Field personnel should routinely use lines and polygons to calibrate their visual estimates of percent cover.

Offsets

When lack of access prevents the GPS unit from being brought to a *Spartina* patch to record its location, yet the patch is clearly visible such that its dimensions can be

confidently estimated and the probable species identified, the *Spartina* should be represented by offsetting a map feature. A GPS position combined with an offset can record the location of a feature that remained a distance from the GPS unit. The offset is comprised of a bearing (measured using a compass and a visual estimate of distance). Offsets are also be used as a surveying aid for accessible *Spartina*, such as to position a line feature along the centerline of a linear *Spartina* patch when the GPS unit is more easily carried along one side of the patch than the other.

Reaches and Endpoints

The shorelines of the Estuary can be subdivided into geo-referenced reaches. A reach typically consists of 200 m to 2000 m of shoreline having fairly consistent physical characteristics. End points that demarcate the ends of reaches typically coincide with prominent physical features, such as jetties, creek mouths, corners of buildings, streets, or changes in dominant perennial vegetation. The location of "endpoints" is recorded by the GPS units, and serves to define and locate the reaches. Reaches and their endpoints are typically named after local features (e.g. "Crown Beach" or "End of Miller Avenue"). Each reach is uniquely coded. Endpoints that are shared by two reaches (i.e., endpoints that mark the end of one each and the start of another) are labeled with the codes of the two associated reaches. Careful descriptive naming of reaches and endpoints provides a means for confirming locations if they are revisited in the future, such as during subsequent mapping efforts.

Discrete areas such as islands or large marshes can also be defined as reaches. If the area is clearly apparent on a topographic map or aerial photo, the feature can be located and digitized in the computer lab and endpoints are not necessary. If the area is not clearly apparent on a map or photo, its location should be recorded with an endpoint or line on the perimeter or within the area, and paper topographic maps should be hand-marked to indicate the area. Some endpoints, such as those associated with island reaches and those adjacent to lands not yet assigned to a reach, will have only one associated reach number; in these cases, the second number is set to zero (see data dictionary in Appendix 1).

Reaches and their endpoints provide an organizational framework for *Spartina* features in the database, a series of geo-referenced landmarks, and they also serve to record inaccessible, un-surveyed segments of shoreline and segments that are surveyed but found to contain no invasive *Spartina*.

Reach Markers

The reach marker feature is a GPS tool used to assign information to a reach. In some cases, the surveyor may record a large area of *Spartina* as a reach, rather than a point, line or polygon. In such cases, a reach marker is used to record the percent cover for the reach. This technique is used when *Spartina* clones are too numerous within an area to GPS individually in an efficient manner, when a discrete area such as an island is not accessible but can be given an estimated percent cover based on binocular survey, and/or when a mapping area is too large to be efficiently surveyed on the ground. Aerial photos may be used in conjunction with field work to estimate percent cover and define the

shape of the reach. Reach markers are also used to indicate surveyed reaches that have no invasive *Spartina*, by assigning these reaches a percent cover of "0%," and to indicate inaccessible reaches that were not surveyed. If individual *Spartina* features are recorded within a reach, reach markers are not used.

Data Sheets

In addition to data entry into the GPS units, paper data forms (Appendix 2) are used to record reach names, numbers, endpoints, and any other field information that did not have a place in the GPS units' database. The mapping database (see Appendix 1) should be designed to minimize the need for handwritten notes.

Field-marked Topographic Maps

Standard, 1:24,000 scale paper topographic maps produced by the US Geological Survey can be hand-marked in the field to record endpoint locations and reach numbers, record unusual reaches or *Spartina* features, or to make other notations relevant to the mapping effort. Information that is redundant with that entered in the GPS units serves as a source of confirmation, error-checking, and clarification if needed.

Tissue Sampling

Many clones of hybrid *Spartina* display traits which allow for reasonable field identification. Field methods for determining plant species or hybrids include

Figure 3. Comparison of stem color of field-identified
S. alterniflora (left) and *S. foliosa* (right).

morphological observations, especially differences between adjacent patches. For example, *S. alterniflora* typically appears taller and more robust than *S. foliosa*, and the lowermost portion of the stems of *S. alterniflora* typically have a red coloration, while the stems of *S. foliosa* appear green or white. Any red coloration is indicative of *S.*

alterniflora or hybrid. (see Figure 3.) Hybrid culms may or may not appear red, however. For those hybrid clones that are morphologically similar to *Spartina foliosa*, only DNA analysis can provide positive species identification. Tissue sampling is not required for *S. densiflora*, *S. patens* or *S. anglica*, since they do not hybridize.

A tissue sample consists of a 5 to 15 cm section of leaf, numbered directly with a permanent felt pen and placed in a labeled plastic Ziploc bag (see Figure 4). Plant tissue samples are then refrigerated until delivered or mailed overnight to a reputable laboratory for genetic testing. Using Randomly Amplified Polymorphic DNA (RAPDs) five primers with previously determined species-specific bands for *S. alterniflora* are used to confirm samples as native *S. foliosa* (zero bands), hybrid (any intermediate number of bands) or non-native *S. alterniflora* (5 positive bands) (Ayres *et al.*, 1999).

Figure 4. Taking a tissue sample.

A budget of three to five plant sample units of suspected *S. alterniflora* or hybrids per reach is suggested to confirm field identification at the reach scale. The sample units should be taken from different areas of each reach. During the mapping effort, field biologists may sample tissues for a variety of reasons, including to verify that a previously un-invaded site has become invaded or has remained "pure," to routinely confirm field identifications, to identify ambiguous plants, or to establish various invasion "conditions." Depending on the site-specific purpose, sampling may be random or targeted and the sample size will vary. The identification of all mapped plants, along with associated data such as tissue sample numbers, is recorded in the mapping database.

Logistics

Field Transportation

During land-based mapping surveyors typically access the marshes by car or bicycle using levees and trails, or are on foot. Kayaks are used for mapping from the water. In general, bicycles are most efficient where long stretches of shoreline are accessible, and kayaks are used only when shoreline access from the land is a problem. Maps provided by the California State Automobile Association and the San Francisco Bay Trail Association can aid navigation and planning.

When possible, two surveyors should work in tandem, and "leapfrog" each other as they map features along the shoreline. Teams of at least two field workers also provide a measure of safety. The use of reach names and other coding must be carefully coordinated among field workers.

Access

The shorelines of the Estuary comprise a wide variety of developed and undeveloped, private and publicly held lands with many types of uses. Access is a frequent issue. Surveyors should contact landowners to gain access to private and military lands. Alternatively, mapping by kayak to access shoreline *Spartina* through the public waterways, and using "offsets" (see above) to define *Spartina* patches is often a practical solution to many access problems. If no access is possible, the area is designated as an inaccessible, un-surveyed reach.

Equipment

A list of materials typically used in the field is provided in Appendix 3.

Time of Year

Optimal field conditions for mapping tend to occur in summer and early fall, when Spartina growth is peaking, such that field identification is easiest. There is a lag time between flowering of *S. alterniflora* and *S. foliosa*. Therefore, degree of flowering can aid field identification, if used in conjunction with other distinguishing characteristics. The timing of flowering is more variable for hybrids than for any of the pure species.

Scoping a Project

Any mapping project faces tradeoffs between completeness, accuracy, and budget and time constraints. The following factors should be considered when defining the scope of a mapping effort.

?? In general, all solitary *Spartina* clones less than 1 meter in diameter are not mapped. ("Solitary" is roughly defined as an absence of other clones within 50-100 m). However, new invasions may be mapped in great detail, even if clones are small.

?? In general, dimensions (e.g. the diameter of clones, width of linear patches, diameter of points, offset distances, etc.) are estimated visually, without the use of tape measures or other measuring devices.

?? If the surveyor is confident, based on a field assessment, that a plant or group of plants is the native *S. foliosa,* the plant is not mapped.

?? If several clones are found in close proximity (roughly, within 20 m of each other), they are typically mapped as a single point feature. The diameter of this point is chosen such that the area produced is equivalent to the total area covered by the group of plants being mapped. In other words, the researcher should estimate the diameter of the circle that would contain the plants *were they all arraigned in a contiguous, circular patch*.

?? If a clone or group is accessible, yet getting to the actual location of the plants would be time consuming, and a good estimate of the distance to the plants is possible, the location of the *Spartina* can be recorded using an offset GPS position. An example of such a situation would be mapping along a 30 m wide

channel with infrequent access to the opposite bank; plants on the opposite bank could be efficiently recorded using offsets.

?? The time required to build relationships with landowners, prepare access permits, schedule tours of private lands, edit GPS data, etc., should be considered in addition to the time of actual field work. The current regional map of NIS *Spartina* that includes South Bay, Central Bay, and North Bay required over seven months of dedicated time, while working within the constraints imposed by sensitive wildlife, tides, weather, and accessibility problems. The seven-month effort involved 75 days of actual field work, with 1 or 2 field surveyors. Rain prevented levee access for 7-10 days, and storms can delay a kayak trip for over two weeks. Before the arrival of the GPS units, initial reconnaissance was conducted in areas where invasive *Spartina* was NOT expected to be found. Once the GPS units were available, mapping efforts became more concentrated. Tides often dictate mapping schedules, with low tide hours being more appropriate for ground-based mapping, and high tide mornings well-suited for surveys using kayaks.

Methods for Areas of Uncertain Invasion

Mapping efforts during 2000-01 concentrated on the South Bay and Central Bay as the main subregions of the NIS *Spartina* invasion. Cursory reconnaissance was conducted in the North Bay and Suisun. During 2001-02, the intensive mapping effort will be extended into North Bay, Carquinez Strait, parts of Suisun Bay, and their adjacent rivers and tidal marsh systems. These subregions together contain much larger amounts of tidal marsh than either the Central Bay and South Bay, but historically they contain very little NIS *Spartina*. In order to efficiently map these subregions with available resources, the mapping effort will focus on a subset of tidal marshes that are recommended by the Technical Advisory Committee of the ISP and additional local biologists as likely places for NIS *Spartina* introduction, based on tide and current patterns, salinity regime, and proximity to known NIS Spartina populations. It is likely that new restoration sites will be targeted for surveys of possible NIS *Spartina* as the sites become colonized by intertidal vegetation. The intent of the extended mapping effort in these subregions is to delimit the boundaries of local, pioneering patches or populations of NIS *Spartina*. The selected subset of tidal marshes will be evaluated according to the following procedure.

?? For *Spartina alterniflora* or its hybrids, tissue samples for genetic analysis will be collected at regular intervals of 25 to 50 m along five random transects in the lower intertidal zone normal to the foreshore at each candidate marsh and extending between the foreshore and backshore. In addition, any observed patches of *Spartina* that appear to be NIS *Spartina* will also sampled. Transect endpoints and the center points of other patches of *Spartina* that are sampled will be recorded using GPS. If all genetic tests for a marsh indicate native *Spartina foliosa*, then no further survey or mapping will be done in that candidate marsh. If tests indicate the presence of NIS *Spartina*, then the usual process of mapping

as described above for areas of known invasion will be initiated for that marsh and extended into adjacent marshes, until subsequent genetic tests from the extended mapping reveal the limits of the local invasion.

?? For NIS *Spartina* other than *S. alterniflora* or its hybrids, it is expected that local patches or populations will be small and easily recognized at this early stage of their invasions. Patches of these NIS *Spartina* will be mapped as points or polygons using GPS as described in the methods above.

?? A network of field biologists will be formed to report any local patches of NIS *Spartina* including patches that should be genetically tested. Each member of the network will be provided with a base map on which the patches of known or suspected NIS *Spartina* will be noted. The ISP will follow up these reports with field checks and tissue samples as required.

Data Management and Use of GIS

The data collected through the GPS units should be downloaded to a desktop computer, differentially corrected, and backed up. Handwritten data should be typed into the database and/or used for verification of GPS data, as appropriate. Each day of field work should be kept in a separate file in the database. When DNA test results are received, species identifications are entered or corrected as required. All data must be scrutinized for errors of transcription, transposition, false zero counts, obviously erroneous values, missing values, incorrect formatting, incorrect units of measurement, spelling mistakes, etc. Different versions of the data set must be coded for date of revision and its authorship.

When any portion of the data set is considered final, it can be imported into ArcView or a comparable program for spatial analysis. The spatial analysis software is used to assign widths to lines and diameters to points, such that they can be converted into polygons. Also at this time, any areas delineated by hand on paper maps or photographs are digitized and included in the database. Local maps can be used to help define the boundaries of patches or reaches that are sketched in the field. The digital versions of the topographic maps produced by the US Geological Survey (known as USGS DRGs or Digital Raster Graphics), and the digital baylands maps contained in the EcoAtlas Information System are especially helpful in this regard.

When the entire project data set has been subject to all the quality control checks and formatted for spatial analysis, then maps can be produced to display the distribution and abundance of *Spartina.* Basic spreadsheet software can be used to calculate acreage, patch size-frequency and other summaries of field conditions. The complete data set and its summaries should be made available to all interests, private or public.

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Appendix 1

Data Dictionary for Regional Mapping

Spartina Map Data Dictionary, Version 6

Used in the creation of the 2000-2001 base map.

Data Dictionary Text	Explanations of Text	Field definition
I. Spartina point feature	For individual plants, or clusters of plants, or to mark roughly circular shape of meadow.	
date GPS'd		date, auto, ymd, not_permitted, manual
Surveyor Name		menu, required
"S. Klohr"		
"D. Smith"		
"K. Zaremba"		
"Other"		
Site code name		text, 30
Reach ID #		numeric, 0, 0, 50000, 0, required
Species	"knowns" are for DNA tested plants	menu
"S alt lab tested"	Use only if lab results indicate 100% S. alterniflora	
"S alt/hyb field ID"	Use if no prior lab testing, field i.d. only	
"Hybrid lab tested"	Use only if lab results indicate hybrid S. alt	
"unknown S alt/fol"	Unable to identify in field. Needs testing and/or revisit.	
"S. anglica"		
"S. densiflora"		
"S. patens"		
"S. foliosa"	Use to mark lab tested foliosa, or to indicate foliosa populations.	
"other/add comments"		
Point represents:		menu, required
"single plant"		
"cluster of plants"	Use to mark closely clustered plants, or as quick mapping technique to indicate # of plants in general area.	
"seedling(s)"		
"DNA test only(notes)"	Use if large area of unknown S. alt/hybrid, and need lab test before can map area. Usually indicates no size or % cover info will be included. Will need to revisit sites if S. alt/hybrid lab results.	
"other: see comments"		
# clones at point		numeric, 0, 0, 5000, 0,
Clone ID name/#	Use if tracking specific clones.	text, 30
Diameter plant/clus	Diameter of plant OR cluster. If cluster, give estimate of total area covered by clones, in diameter measure.	numeric, 2, 0.00, 500.00, 0.00,
DNA sample site?		menu
"yes"		
"no"		
"not applicable"		
DNA sample name/#	Name given to lab for tracking.	text, 30
Confidence level	Confidence of mapping and plant identification. Relates to distance from plants at time of i.d., phenology of plant, source of location information.	menu

"high"	Plants identified at close range, and/or in peak phenology, and/or with lab testing.	
"moderate"	Plants identified at moderate distance (i.e. with binoculars, via kayak from shore); and/or at non-peak phenology; and/or used % cover estimate. May be location information from reliable source, but unsurveyed by members of ISP.	
"lower"	Plants identified from distance; and/or quick survey via airboat or other vehicle; and/or plants in senescence; and/or unverified location information from questionable source; and/or gross % cover estimate.	
Comments		text, 50

II. Spartina line feature   For noting accessible edges of polygons (will be converted to poly's in GIS), and linear infestations. Also used to collect useful feature info for GIS, such as total length of reach, or width of infested channel.

date GPS'd		date, auto, ymd, not_permitted, manual
Surveyor Name		menu, required
"S. Klohr"		
"D. Smith"		
"K. Zaremba"		
"Other"		
Site code name		text, 30
Reach ID #		numeric, 0, 0, 50000, 0, required
Species	"knowns" are for DNA tested plants	menu
"S alt lab tested"		
"S alt/hyb field ID"		
"Hybrid lab tested"		
"unknown S alt/fol"		
"S. anglica"		
"S. densiflora"		
"S. patens"		
"S. foliosa"		
"other/add comments"		
Defines reach?		menu
"yes"	Reply "yes" only if line indicates entire length of reach.	
"no"	If line only indicates feature within a reach.	
% cover/reach only	Use only if line represents entire reach. Skip if not the case.	menu
"0%"		
"<1% (seedlings)"		
"<1% (mature)"		
"1-10%"		
"10-30%"		
"30-60%"		
"60-90%"		
"90-100%"		
"DNA results needed"	Use if cannot give %cover until know lab results of species.	

    "n/a"

Defines feature only   menu

    "yes"   Use if line defines feature within a reach.

    "no"

Ave clone size/line   For informational purposes only. Not for calculating total acreage.   menu

    "seedling to 1m"

    "1 m - 3m"

    "3m - 10m"

    "10m - 30m"

    "30m +"

    "meadow"

    "other: see comments"

Width of feature   Width will be used in GIS to expand line into polygon. Give average   numeric, 0, 0, 500, 0,
width of infestation along line.

% cover/feature only   Use to indicate % cover of polygon the line represents. This will be   menu
used to calculate total acreage. Also, can be quick method to map %
cover by Spartina of an entire channel bed (subtract open water portion
from total width, give %).

    "0%"

    "<1%, seedlings"

    "1-10%"

    "10-30%"

    "30-60%"

    "60-90%"

    "90-100%"

    "n/a", default

Confidence level   menu

    "high"

    "moderate"

    "lower"

Comments   text, 50

III. Spartina area feature

date GPS'd   date, auto, ymd, not_permitted,
manual

Surveyor Name   menu, required

    "S. Klohr"

    "D. Smith"

    "K. Zaremba"

    "Other"

Site code name   text, 30

Reach ID #   numeric, 0, 0, 50000, 0

Species   "knowns" are for DNA tested plants   menu

    "S alt lab tested"

    "S alt/hyb field ID"

    "Hybrid lab tested"

    "unknown S alt/fol"

    "S. anglica"

"S. densiflora"

"S. patens"

"S. foliosa"

"other/add comments"

Defines reach?   menu

    "yes"   Use if able to access all of reach, if need to delineate isolated
                                     population.

    "no"

% cover/reach only   Use only if polygon represents entire reach.   menu

    "0%"

    "<1% (seedlings)"

    "<1% (mature)"

    "1-10%"

    "10-30%"

    "30-60%"

    "60-90%"

    "90-100%"

    "DNA results needed"

    "n/a"

Ave clone size/reach   Use only if polygon represents entire reach.   menu

    "seedling to 1m"

    "1 m - 3m"

    "3m - 10m"

    "10m - 30m"

    "30m +"

    "meadow"

    "other: see comments"

    "n/a", default

Defines 1 clone?   menu

    "yes"   Use if GPS'ing perimeter of clone.

    "no", default

Defines cluster?   menu

    "yes"   Use if GPS'ing perimeter of cluster.

    "no", default

Ave clone size/clust   For informational purposes. Will not be used to calculate acreage.   menu

    "seedling to 1m"

    "1 m - 3m"

    "3m - 10m"

    "10m - 30m"

    "30m +"

    "meadow"

    "other: see comments"

 # clones in cluster   numeric, 0, 0, 5000, 0

% cover/feature only   Will be used for calculating total acreage.   menu

    "0%"

    "<1%, seedlings"

    "1-10%"

    "10-30%"

    "30-60%"

    "60-90%"

    "90-100%"

    "n/a", default

Confidence level   menu

    "high"

    "moderate"

    "lower"

Comments   text, 50

IV. "Other Plant Species", point

Use if want to mark other invasives, rare plants, etc.

date GPS'd   date, auto, ymd, not_permitted, manual

Surveyor Name   menu, required

    "S. Klohr"

    "D. Smith"

    "K. Zaremba"

    "Other"

Site code name   text, 30

Species   text, 40

Comments   text, 100

V. "Reach Marker", point

Use ONLY if assigning % cover to a reach. Do not use if have GPS'd all individual or clusters of plants within reach. Use to indicate reaches of 0% cover.

date GPS'd   date, auto, ymd, not_permitted, manual

Surveyor Name   menu, required

    "S. Klohr"

    "D. Smith"

    "K. Zaremba"

    "Other"

Reach #   numeric, 0, 0, 50000, 0

Site code name   text, 30

Species marked: Menu items indicate which species surveyor was looking for in area. If more than one invasive Spartina species is in reach, or in adjacent reaches, create separate reach markers for each species surveyed. Most areas will only be indicated as survey for "S. alt/hybrids." Assume 0% invasive Spartina if area surveyed and has no reach marker or GPS points for clones.   menu

    "S alt and hybrids"

    "S densiflora"

    "S patens"

    "S anglica"

    "S foliosa "

    "unk: DNA test needed"

    "No invasive Spartina"   Use if survey revealed 0% of any invasive Spartina. (note: default will often be 0% S. alt and hybrids)

    "other/see comments"

% Cover/Reach	Use to assign % cover to well-defined areas only. Will be used to define acreage. *Note: Cannot calculate acreage if cannot define total area. Indicate boundaries of area on map or photo, or with GPS points.	menu

"0% identified"

"<1% (seedlings)"

"<1% (mature)"

"1-10%"

"10-30%"

"30-60%"

"60-90%"

"90-100%"

"DNA results needed"

Ave clone size/reach	menu

"seedling - 1m"

"1m - 3m"

"3m - 10m"

"10m - 30m"

"30m +"

"meadow"

"other: see comments"

"unknown"

Confidence level	menu

"high"

"moderate"

"lower"

Comments	text, 50

VI. "Reach endpoint", point

Dividing line between reaches. Usually a landmark feature. If endpoint is at dead-end of feature, one reach will be called 0.

Between reach # ...		numeric, 0, 0, 50000, 0
and reach #...		numeric, 0, 0, 50000, 0
endpt landmark	Indicate landmark feature that marks endpoint, if possible.	text, 30
Comments		text, 30

VII. "Landmarks", point

landmark menu	menu

"PG&E tower"

"PG&E boardwalk"

"creek mouth"

"slough mouth"

"telephone pole"

"boat wreck"

"boat launch"

"dock"

"gate"

"sign"

"tree"

"bridge"

"building"

"culvert"

"dredge lock"

"tide gate"

"parking area"

"levee"

"road"

"trail"

Other landmark   text, 30

Comments   text, 30

VIII. "Point Generic", point

date GPS'd   date, auto, ymd, not_permitted, manual

Surveyor Name   menu, required

"S. Klohr"

"D. Smith"

"K. Zaremba"

"Other"

Site Code   text, 30

Comments   text, 100

IX. "Line Generic", line

date GPS'd   date, auto, ymd, not_permitted, manual

Surveyor Name   menu, required

"S. Klohr"

"D. Smith"

"K. Zaremba"

"Other"

Site Code   text, 30

Comments   text, 100

X. "Area Generic", area

date GPS'd   date, auto, ymd, not_permitted, manual

Surveyor Name   menu, required

"S. Klohr"

"D. Smith"

"K. Zaremba"

"Other"

Site Code   text, 30

Comments   text, 100

Appendix 2

Sample Paper Data Sheet from 2000–2001 Mapping

Date: 1/16/01
Names: Katy & Laura m. / Deb G.
Low Tide (hr/ft):
Mapping hrs: 13.0 – 0.00
Rover file: 7021617A / R021617A

Plus Setup (Name / time)

#	End Pt # to:	End Pt/Landmark Name	Reach #	Reach Name	Notes
1	0 – 132	Oak Fire Dept Stn B	132	Jack London SRA Oak Inner Harb.	✗ 5 samples Tbd (1-5) Sights
2	132 – 133	Lake Merrit Channel mouth	133	Lake Merrit Channel	✗ 2 sample LMC - 1 previously sampled. Spotted plant at Naha over sampled LMP-1
3	133 – 134	Lake Merrit Mouth	134	Lake Merrit	1 scatt. previously GPS'd by boat house. File R110819A
4	134 – 135	Lake Merrit Channel mouth SE	135	5th Ave Marina	→ unsuccessful/no Access (turn on walk? or sl Permit?
5	135 – 130	9th Ave Terminal	130	Embarcadero Cove	(Includes Clinton Basin)
6	130 – 137	Government Isl. Bldg	137	Government Isl.	✗ Return to Survey '3'?
7					
8	136 – 126	Almagra Bldg	126		→ Return to Survey on Almeda AC
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

Appendix 3

Field Mapping Supplies

GPS unit (Trimble GeoExplorer 3 or equivalent)
Paper data sheets (on waterproof paper for kayak trips) (see Appendix 2)
Covered clipboard
1:24,000 scale USGS paper topographic maps
Aerial photos, if available
AAA regional maps or equivalent
Bay Trail maps
Pencils
Permanent Marker for marking tissue samples
Ziploc bags for collecting tissue samples
Compass
Binoculars
Camera and film
Appropriate permits to access private lands
Rubber boots
Kayaks with safety gear
Bicycles
4-wheel drive Vehicle
100-m measuring tape for transects