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San Francisco – Oakland Bay Bridge
East Span Seismic Safety Project

Eelgrass Habitat Surveys
(October 1999, 2000, and 2001)

November 2001

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November 2001

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SAN FRANCISCO - OAKLAND BAY BRIDGE EAST SPAN SEISMIC SAFETY PROJECT
EELGRASS HABITAT BASELINE PRE-CONSTRUCTION SURVEYS (OCTOBER 1999, 2000, AND 2001)

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NOVEMBER 2001

1.0 INTRODUCTION

The California Department of Transportation (Caltrans) will replace or retrofit of the East Span of the San Francisco – Oakland Bay Bridge (SFOBB) as part of seismic upgrades to improve bridge safety in the state. This project, termed the San Francisco – Oakland Bay Bridge East Span Seismic Safety Project (East Span Project), has the potential to impact existing natural eelgrass communities both during and following construction.

1.1 PROGRAM OBJECTIVES

To better assess the status of eelgrass within the project area and to aid in evaluating impacts and developing methods to minimize and mitigate potential impacts, eelgrass surveys have been completed by Merkel & Associates, Inc. over three consecutive baseline years. Surveys have been completed in October 1999, 2000, and 2001 to correspond to the peak extent of eelgrass during the summer growing season prior to entering into a winter dormancy and dieback period., Surveys were conducted within and near the construction work areas for the touchdowns of the East Span Project at both Yerba Buena Island (YBI) and the Oakland Touchdown. Construction work areas mapped and discussed within this document include areas of physical distribution or anticipated navigation uses located in the vicinity of eelgrass beds. In addition, reference areas more removed from the immediate project area were also surveyed within the boundaries of large survey blocks.

This document transmits information from the three baseline surveys and has several objectives:

1. To document the methods, conditions, and analytical approach taken in conducting field surveys and data interpretation for the eelgrass surveys;

2. To provide an accurate characterization of the distribution, abundance, and density of eelgrass habitat within the vicinity of the proposed project and reference areas;

3. To evaluate and interpret interannual eelgrass bed dynamics within the survey area and explore the natural fluctuations in eelgrass density and coverage observed between 1999, 2000, and 2001; and,

4. To serve as a pre-construction survey for assessing impacts to eelgrass resources associated with project construction and provide data for a comparative analysis with construction and post-construction surveys.

This report includes portions of the 1999 survey data from a larger survey area surrounding the bridge (Merkel & Associates, 2000a). This report format provides compiled data and aids in the presentation of analyses of eelgrass dynamics within the study area.

1.2 EELGRASS BACKGROUND

1.2.1 General

Eelgrass (*Zostera marina* L.) is a native marine vascular plant indigenous to the soft-bottom bays and estuaries of the Northern Hemisphere. The species' range extends from Baja to northern Alaska along the West Coast of North America and is common in shallow bays and estuaries. Within the southern portion of its range, eelgrass growth is generally limited at the shoreward edge by desiccation stress at low tides. Throughout its range, eelgrass is generally limited along its deeper fringe by light limitation, expressed as the photocompensation depth (the depth at which photosynthesis is unable to meet the metabolic demands of the plant to sustain net growth). Eelgrass meadows occur within the shallow bay habitats and in the more saline brackish water interfaces of the San Francisco Bay estuary.

1.2.2 Functions and Values

Eelgrass plays many roles within the estuary system. It clarifies water through sediment trapping and habitat stabilization, (Wyllie-Echeverria and Rutten 1989). It also provides benefits of nutrient transformation and water oxygenation. Eelgrass serves as a primary producer in a detrital based food-web and is further directly grazed upon by invertebrates, fish, and birds, thus contributing to the system at multiple trophic levels. Eelgrass also provides physical structure to the community and supports epiphytic plants and animals that, in turn, are grazed upon by other invertebrates, larval and juvenile fish, and birds. Studies in San Francisco Bay and other aquatic systems in California have demonstrated the abundance of fish and invertebrates within eelgrass habitats (Hoffman 1986, Kitting 1994).

Eelgrass is a nursery area for many commercially and recreationally important finfish and shellfish species including those that are resident within bays and estuaries, nearly all of the anadramous fish species found along the Pacific coast, and oceanic species which enter the estuaries to breed or spawn. Pacific herring regularly spawn on eelgrass leaves and salmonid fry and smelt often spend extensive amounts of time within eelgrass habitats prior to heading for the open ocean. Among other recreationally important species, striped bass and sturgeon make uses of eelgrass beds as habitat within San Francisco Bay. Finally, eelgrass habitat supports a high diversity of non-commercially or recreationally important species whose ecological roles are less well appreciated or understood. Besides providing important habitat for fish, eelgrass habitat also is considered to be an important resource supporting migratory birds during critical life stages, including migratory periods. Eelgrass is particularly important to waterfowl such as black brant that feed directly on the plants and a number of species that make a diet of both the eelgrass plants and the epiphytic growth that occurs on the leaf tissues.

1.2.3 San Francisco Bay Eelgrass Resources

The San Francisco estuarine complex is the second largest estuary in the nation and the largest estuary on the Pacific Coast, consisting of approximately 456 mi^2 (1,180 km^2) of water surface at high tide. In the late 1920s, eelgrass was reported as an abundant species along the shores of San

Francisco Bay (Setchell 1929). More recently, a 1987 National Marine Fisheries Service (NMFS) survey of the Bay revealed only 316 acres (128 hectares) (0.1% total Bay bottom coverage) of eelgrass throughout the Bay with much of the existing habitat exhibiting conditions of environmental stress (Wyllie-Echeverria and Rutten 1989, Wyllie-Echeverria 1990). In comparison, other bay and estuary systems such as San Diego Bay (11.4%), Mission Bay (55%), Humboldt Bay (approx. 16%), and Coos Bay (approximately 5%) support proportionally much greater eelgrass resources over their entire bay bottoms than does San Francisco Bay. Watershed nutrient and sediment loading from the Delta as well as dredging and filling have taken their toll on eelgrass resources of San Francisco Bay; however, conditions are not as bleak as once thought. In October 1996, eelgrass surveys were conducted from Richmond Harbor to just north of Point San Pablo for two separate Army Corps of Engineers project studies (SAIC and Merkel & Associates 1997a, 1997b). These studies were conducted using sonagraphic techniques for eelgrass mapping in turbid environments that were pioneered in southern California (Merkel 1988, 1992, 1998a, US Navy SWDIV 1994). In the 1996 surveys of the Point San Pablo shoreline, 483 acres (32,015 $m^2$of eelgrass beds were identified over this short stretch of shoreline alone. Subsequent surveys have identified eelgrass in numerous locations where it has not previously been known to occur, including along the Oakland and Alameda waterfronts, along portions of the Marin Peninsula, within San Leandro Bay, and at other smaller locations (Merkel & Associates, unpublished data). These data suggest that either a significant expansion of eelgrass habitat has occurred since 1987 or that improved survey techniques have identified more of the resource than was detectable using prior techniques. Even with the expanded knowledge of eelgrass at other locations, the occurrence of eelgrass within San Francisco Bay is as much as two orders of magnitude lower than that found in other large bays and estuaries along the Pacific coast.

The distribution of eelgrass within San Francisco Bay has not been well-documented and there is a lack of data pertaining to eelgrass ecosystem function within the bay. However, lessons from other estuarine systems can be applied to San Francisco Bay. While eelgrass resources within San Francisco Bay are sparse, there is no indication that these resources, on a per area basis, are any less valuable to the natural system of the Bay than to other bays and estuaries. In fact, the general paucity of eelgrass may render its contribution within San Francisco Bay even more important. This is certainly true for species whose biology is tightly coupled with the occurrence of eelgrass, such as the black brandt, which forages nearly exclusively on eelgrass and for which migration along the Pacific flyway is dependent upon having adequate stop-over locations that support eelgrass (Ehrlich et al. 1988). Similar but less tightly coupled relationships exist between eelgrass and several fish and invertebrates that are dependent upon the sheltering structure of developed eelgrass beds. One such species is the Pacific herring which attaches its eggs to eelgrass and other structures for an approximately two-week duration during spawning.

1.2.4 Regulatory Framework for Eelgrass Conservation and Restoration

Eelgrass, as a vegetated shallow water habitat, is protected under the Clean Water Act, 1972 (as amended), section 404(b)(1), "Guidelines for Specification of Disposal Sites for Dredged or Fill Material", subpart E, "Potential Impacts on Special Aquatic Sites". This area includes sanctuaries and refuges, wetlands, mudflats, vegetated shallows, coral reefs, riffle, and pool complexes.

1.3 Description of the Study Area

The SFOBB East Span project study area extends from the eastern shoreline of central San Francisco Bay along Interstate 80 (I-80) from north of the Port of Oakland's Outer Harbor to YBI (Figure 1). The shallow water depths that are potentially suited to the development of eelgrass beds, and thus were the focus of eelgrass surveys, are located at the east and west ends of the existing East Span.

The 1999 survey area included both the north and south sides of the bridge around the east and west abutments and around the bridge approaches. A more restricted survey was conducted in 2000 and 2001 to cover the selected alignment of the new East Span and adequate portions of the surrounding Bay to assess potential project impacts and to serve as appropriate ambient conditions reference areas. The current 2001 survey was also designed to serve as a pre-construction survey prior to initiation of construction activities. Areas surveyed in October 1999, 2000, and 2001 are illustrated on Figure 1.

The survey area includes the touchdown areas at the western and eastern ends of the project site. The western end of the project site consists of Clipper Cove located north of the existing bridge, adjacent to the northern shore of YBI. The eastern end of the project site consists of the Emeryville Flats near Radio Beach, located north of the existing bridge and the Oakland Touchdown area. In 1999, the study area also included Coast Guard Cove to the south of the western touchdown of the existing bridge along YBI, and the Oakland Outer Harbor Flat, a deeper location to the south of the eastern touchdown of the existing bridge.

The eelgrass survey areas range from shallow intertidal elevations (deeper than +0.5m MLLW) to shallow subtidal depths (shallower than -3.0m MLLW). The areas include a variety of exposures to wind waves and currents, and are characterized by variable sediment conditions. The harshest wind and wave environment is found on the Emeryville Flats. Clipper Cove at YBI is the most sheltered environment and is only subject to short-fetch infrequent easterly waves. Sediments within the survey areas range from medium sands along the shallow shoals of Emeryville Flats, to finer silty-sands within Clipper Cove at YBI.

Within the survey area waters are highly turbid along the eastern shoreline and are somewhat less turbid on the western end of the SFOBB East Span (EOSAT/Landsat 5 Imagery for San Francisco Bay). These differences in turbidity from east to west are derived from the additive influence of a substantially greater wave-generated re-suspension of bottom sediments along the Emeryville Flats than found in the more protected waters surrounding YBI. This is similar to the pattern observed along other shallow East Bay shoals such as Bay Farm Island and Richmond Harbor (Merkel & Associates unpublished data). These patterns are further exacerbated by differences in the ambient turbidity levels associated with greater flood tide influences around YBI than at the Emeryville Flats. However, the distribution of eelgrass at these two sites is primarily limited by presence of shallow water habitat, rather than by turbidity levels alone. Only a narrow band of shallow, relatively clearer water occurs at YBI, resulting in the presence of a narrower band of eelgrass than found at Emeryville Flats (Section 3.1).

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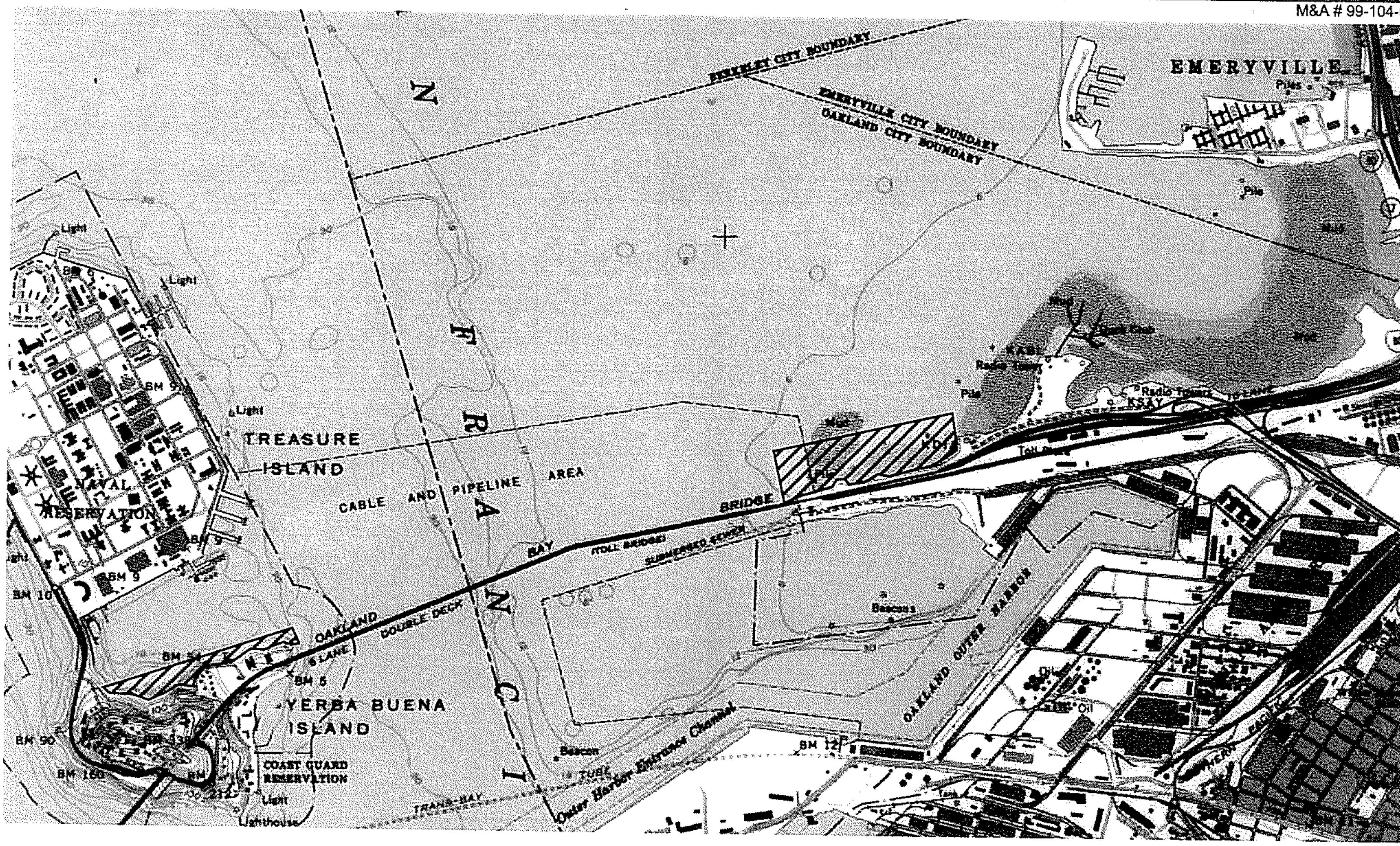


Eelgrass Survey Areas

San Francisco-Oakland Bay Bridge East Span
Survey Area Vicinity Map
(Source: USGS 7.5' Oakland West, CA Quadrangle)

N W E S

Figure 1

Merkel & Associates, Inc.

2.0 SURVEY METHODS

For the surveys, a combination of acoustic (side-scan sonar and down-looking sonar surveys) and diver surveys were used to chart the eelgrass beds and to assess eelgrass patch and bed distribution as well as bed density and turion (shoot) densities within individual eelgrass patches. These methods have been previously used to produce maps of eelgrass distribution and density at the project site (Merkel & Associates 2000a) and have been standard assessment tools for use in the pre- and post-construction eelgrass surveys of Richmond Harbor (SAIC and Merkel & Associates 1997a; Merkel & Associates 1999a), the Baldwin Ship Channel (SAIC and Merkel & Associates, 1997b), along the Richmond – San Rafael Bridge (Merkel & Associates, 1998a), the Oakland Middle Harbor Shoal (Merkel 1999b), Bayfarm Island and Coyote Point (Merkel & Associates, unpub. data), and several sites in southern California (Merkel 1988, 1992, Merkel & Associates 1997c and 1997d, 1998, 1999, and US Navy SWDIV 1994).

2.1 SURVEY TIMING

All three baseline surveys (October 1999, 2000, 2001) were conducted during the fall, at the end of the eelgrass growing season, to take advantage of the peak season for above-ground biomass. By standardizing the survey season, comparisons between survey years could be performed at the maximal extent in the vegetation for the survey year. Survey methods are described below.

2.2 ACOUSTIC FIELD SURVEY METHODS

2.2.1 Navigation

The October 1999, 2000 and 2001 field acoustic surveys involved the integration of a differential global positioning system with side-scan sonar and fathometer systems. Navigation and positioning for the survey were conducted using a Leica MX400 GPS receiver equipped with a differential correction receiver, which utilized the U.S. Coast Guard FM correction beacons. Vessel positional data were linked to an on-board IBM Pentium III PC and integrated with navigation monitors. Data were collected and analyzed digitally using Marine Sonics Sea-Scan PC side-scan data collection software and Oceanic Imaging Consultants GeoDAS analysis software. Survey trackline positional fixes were saved to the computer hard drive along with sonar plots. The system resolution was ±3 meters as a combined error of the navigation system and side-scan equipment. All data were collected in decimal degrees latitude and longitude using the North American Datum of 1983 in feet (NAD 83). The data were then subsequently converted and plotted on a coordinate grid using State Plane coordinates in meters (NAD 83).

The October 1999 survey was conducted aboard the 22-foot vessel Hot Tuna and the October 2000 and 2001 surveys were conducted aboard the 24-foot R/V Merkel-1. Both vessels were operated by Merkel & Associates. During each survey, the vessel operator ran a series of parallel tracklines spaced 20 meters apart to ensure adequate overlap between adjacent side-scan swaths. The first track was run within 10 meters from the shoreline and was positioned so that shoreline features such as rip-rap rubble or beach interfaces could be seen in the survey record. A navigation fix was collected every 2 seconds during data collection. Vessel position was maintained along the tracklines using an on-board, real-time video display with a two-second position refresh frequency and graphic as well as a digital display of velocity and trackline variance.

2.2.2 Side-scan Sonar

Side-scan data were collected using a Marine Sonics side-scan sonar operating at 600 kHz and an EPC 1086 2-channel thermal recorder. Rough water, surface waves, and turbulence can interfere with towfish stability and acoustic records during the surveys. To minimize this interference, the towfish was positioned off the port side of the boat, at about the fulcrum of the boat and the fish was positioned approximately 0.5 meters below the water surface. To obtain good overlap coverage between adjacent tracklines, the side-scan recorder was configured to provide a display range of 20 meters per channel (port and starboard). This configuration allowed for a trackline overlap of 10 meters between parallel tracklines.

2.2.3 Fathometer

Bathymetric data were collected using a Lowrance X16 fathometer operating at a frequency of 200 kHz and a Furuno digital survey fathometer operating at a frequency of 200 kHz. The echo-sounder was mounted on the starboard side of the vessel, with the 15% beam width transducer located approximately 1 foot below the water surface. All fathometer data were recorded on a 0 - 15 foot vertical scale and the gain was adjusted to maximize the detection of eelgrass.

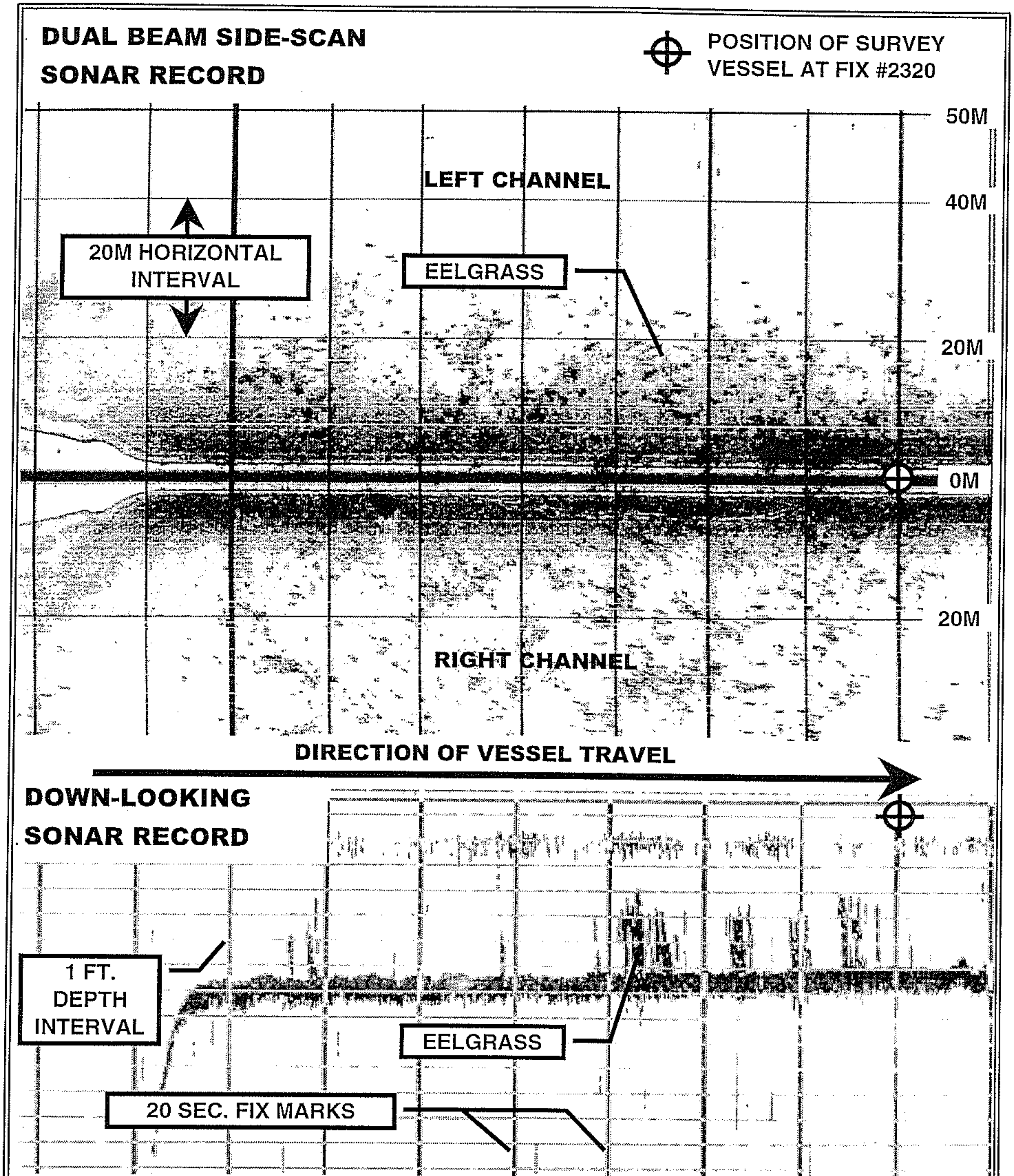
2.3 Dive Survey Methods

Divers were used to ground-truth acoustic records of eelgrass, and to provide estimates of eelgrass shoot densities in identified study and reference patches of eelgrass. For ground-truthing, divers conducted dives at eelgrass positions detected by the acoustic survey vessel. Turion (shoot) density within identified eelgrass patches was determined by counting all of the shoots within a $1/16m^2$ quadrat. Visibility was extremely limited during the surveys so the divers frequently used only their hands to feel for any eelgrass within the quadrat. A total of 71 turion counts were taken during the October 1999 survey, a total of 20 turion counts were taken during the October 2000, and a total of 20 turion counts (ten per survey area) were taken during the October 2001 survey.

Divers were also used to ground-truth acoustic records of eelgrass and to verify specific eelgrass points and other objects within the side-scan images. This was done by divers locating objects and eelgrass and setting reference buoys which were then revisited by the survey vessel to establish a positional fix on the identified objects. This aided in calibrating interpretation of side-scan records. Fallen trees from erosion along the YBI shoreline, piles, and concrete and rock rubble were the only features existing in the survey area that could have been confused with eelgrass.

2.4 Survey Data Interpretation and Eelgrass Mapping

Low intensity acoustic signal returns are frequently difficult to interpret and were generally considered to be noise or unreliable data and were not used in determining eelgrass cover. Such light returns are products of dissipated signal strength that result from partial reflection from near-field features as well as an increasing angle of incidence and great acoustic scatter. Where weak signals existed, overlapping trace records were used to supplement the data. Near-field weak signals in the side-scan record were frequently compensated for using the coincident fathometer data. An example of the use of multiple data sources is illustrated in Figure 2.



Example Data Collected Example Data Collected from San Francisco Bay Acoustic Eelgrass Survey

Figure 2

Because of the sparse occurrence of eelgrass found during the surveys, mapping techniques and areal coverage determination made use of a mix of analytical techniques applied in SAIC and Merkel & Associates 1997a and 1997b, Merkel 1988, 1992, and 1996, 1999, and U.S. Navy SWDIV 1994. A boundary line that defined the spatial extent of what could be defined as an eelgrass bed encompassed clustered eelgrass patches. These beds were further subdivided into areas occurring within differing ranges of areal coverage including 5%-20%, 20%-40%, and greater than 40% cover. A minimum coverage of 5% was used for mapping purposes and to define aggregations of eelgrass plants that constitute a bed. Individual plants were considered to be the boundaries of the bed in instances where individual plants were too far apart to be aggregated into beds achieving 5% plant cover. These patches, like many of the patches that occurred within the beds, were typically comprised of single plants with one or only a few turions. Figure 3 provides examples of the density classifications applied to data collected in October 1999, 2000, and 2001 surveys within the SFOBB survey area.

Following completion of the surveys, sonar traces were downloaded, processed, and geographically registered using ArcView Version 3.1 and 3.2a and eelgrass habitat was heads-up digitized as a theme over an AutoCAD basemap provided by Parsons Brinkerhoff. All plots were generated based on California State Plane Zone 6 (NAD 83).

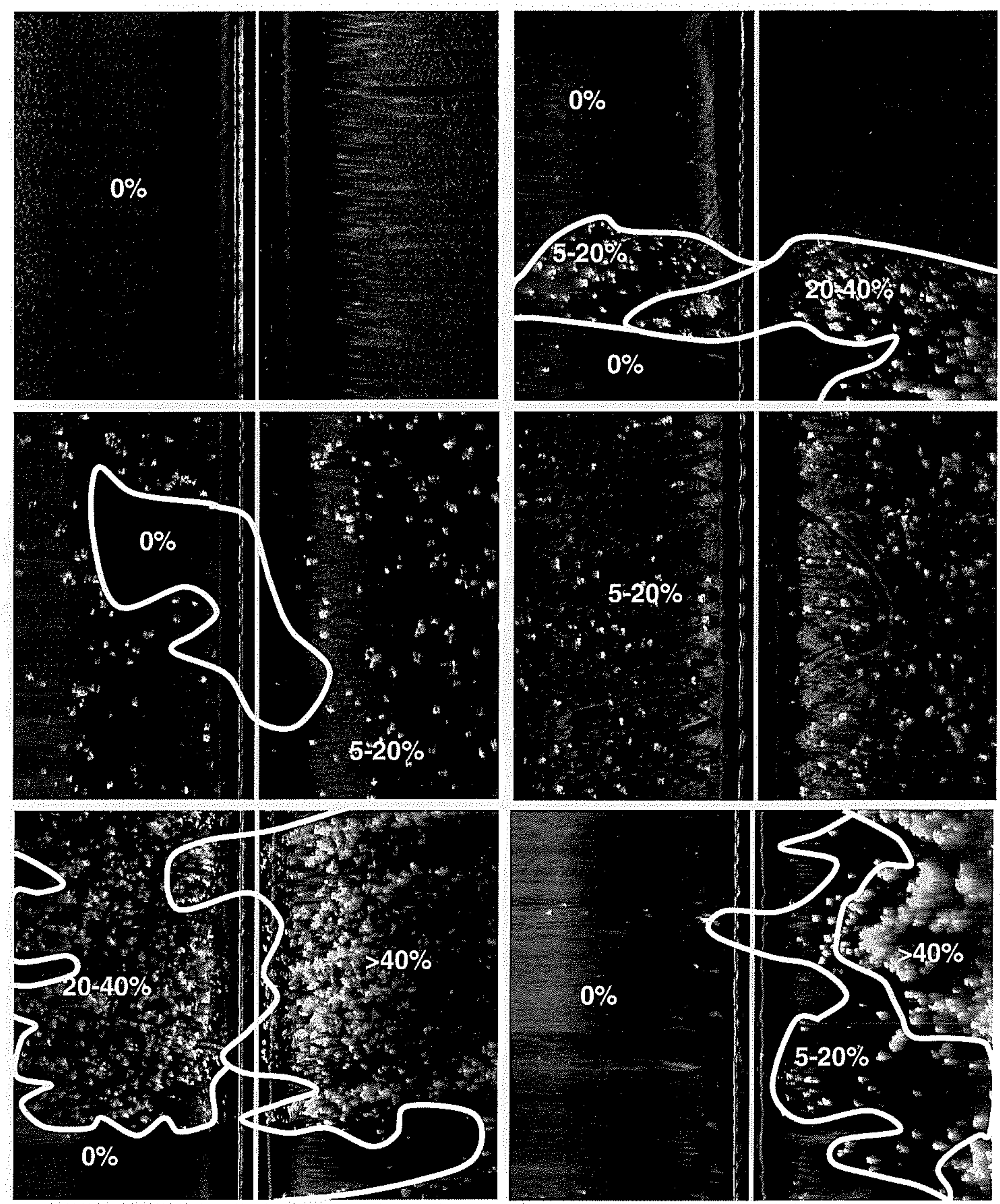
3.0 RESULTS

3.1 EELGRASS BED DISTRIBUTION AND DENSITY

In October 1999, eelgrass occurred on both ends of the East Span. Eelgrass coverage at Emeryville Flats was sparse and coverage at YBI was narrow but appeared limited by a steep depth gradient (Figures 4 and 6). This result is in agreement with similar findings from limited 1997 searches for eelgrass within this area (Merkel & Associates, unpublished data).

The general distribution of eelgrass in October 2000 followed patterns observed in prior surveys with the majority of the eelgrass occurring on the shallow Emeryville Flats and a narrow fringe of eelgrass occurring along the shoreline of Clipper Cove (Figures 4 and 6). The eelgrass distribution in 2000 vastly exceeded that detected in 1999. Steep bathymetry along the shoreline at Clipper Cove resulted in a more restricted expansion than was observed on the Emeryville Flats where minor differences in bathymetry characterize the broad shallows allowing a greater potential for eelgrass expansion.

The current October 2001 survey areas covered the same regions as the October 2000 effort, along Emeryville Flats and within Clipper Cove. Eelgrass distribution in October 2001 was found to closely resemble the October 2000 eelgrass distribution. Again, eelgrass was found to occupy a narrow fringe along the shoreline of Clipper Cove, with the majority of eelgrass occurring on the Emeryville Flats (Figures 4, 5 and 6).



Eelgrass Habitat Density Classification From Side-Scan Survey Records

Figure 3

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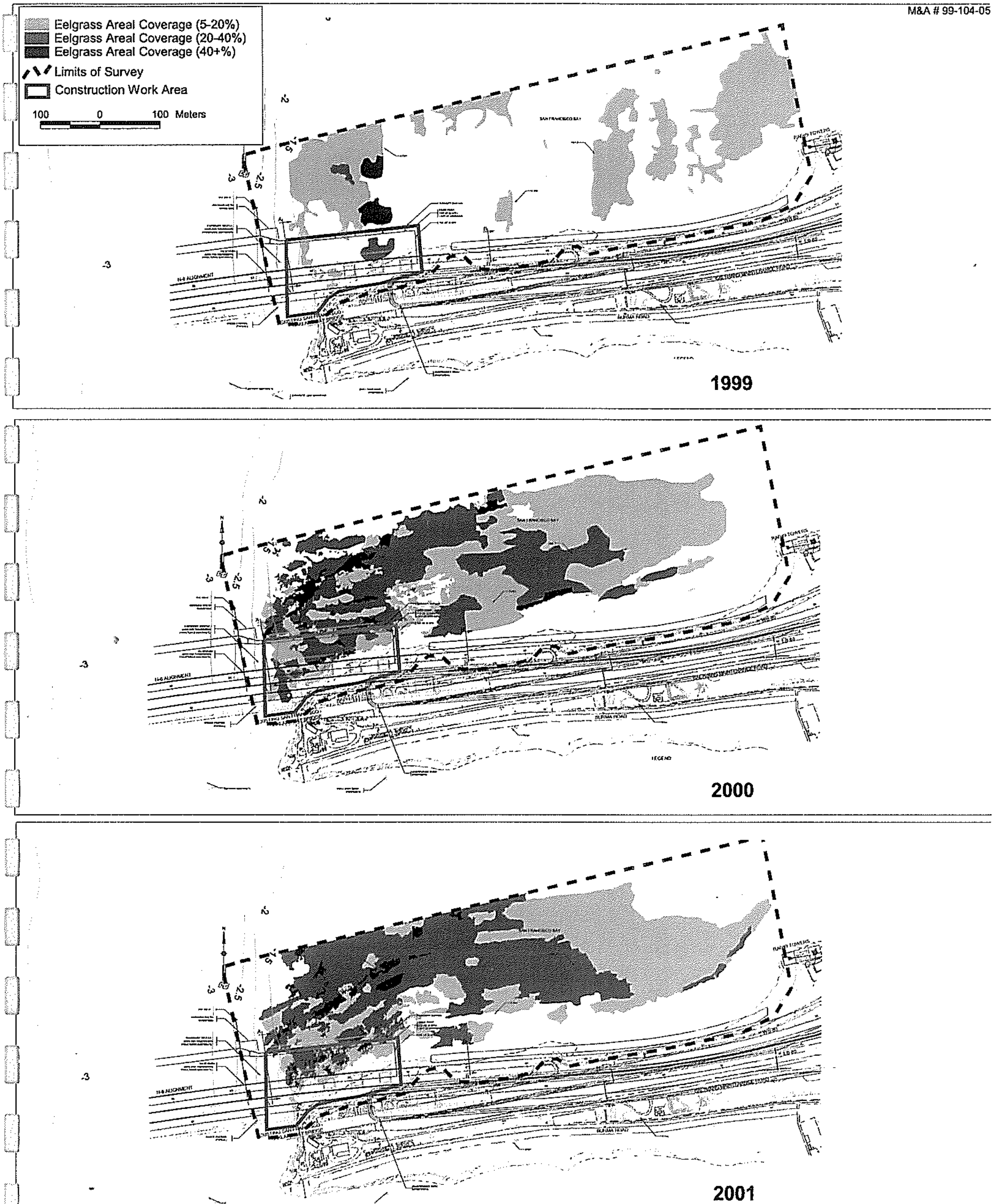

San Francisco-Oakland Bay Bridge, East Span
Eelgrass Survey at the Oakland Touchdown Area
1999-2001

Figure 4

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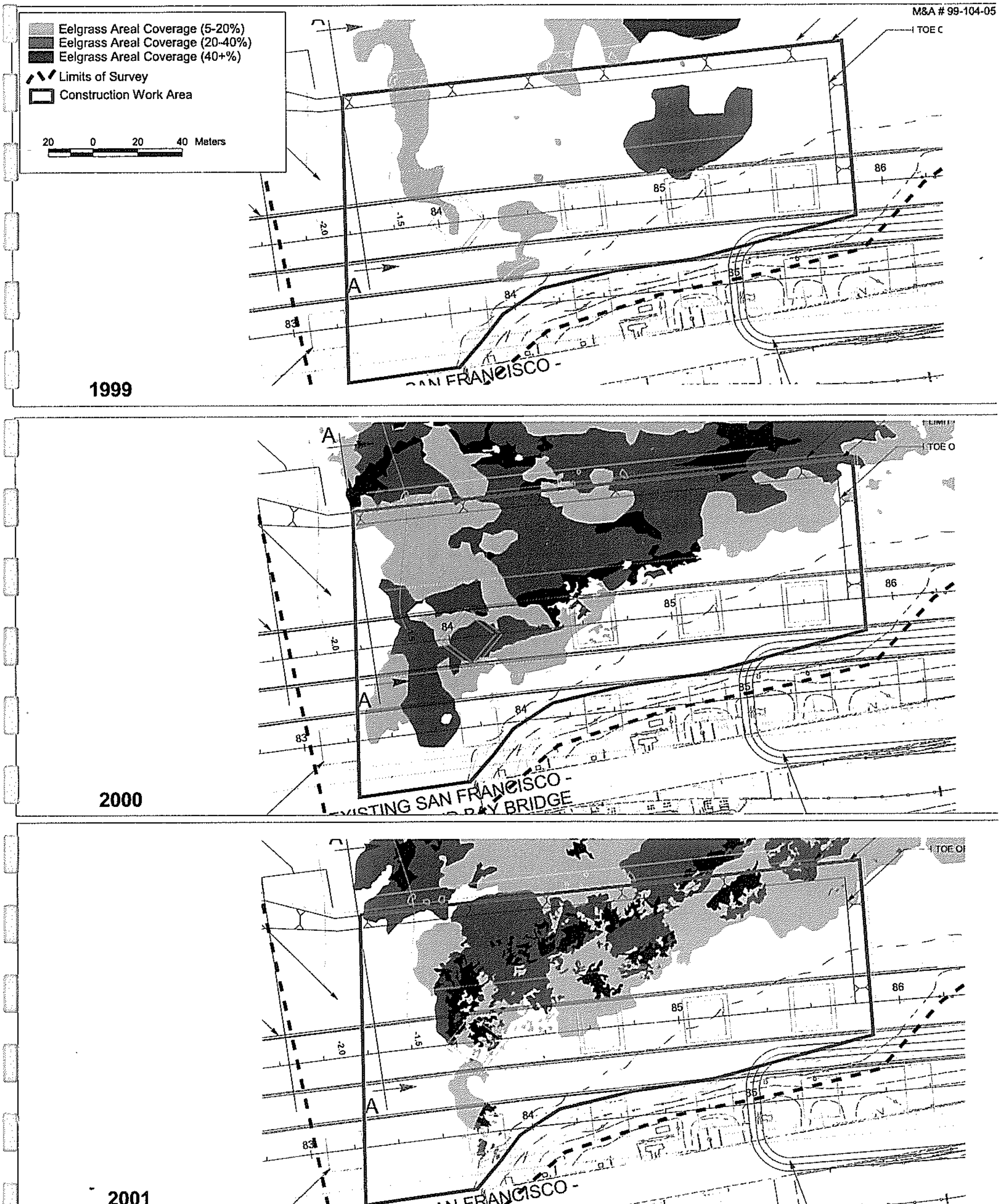

San Francisco-Oakland Bay Bridge, East Span
Eelgrass Survey at the Oakland Touchdown Construction Work Area
1999-2001

Figure 5

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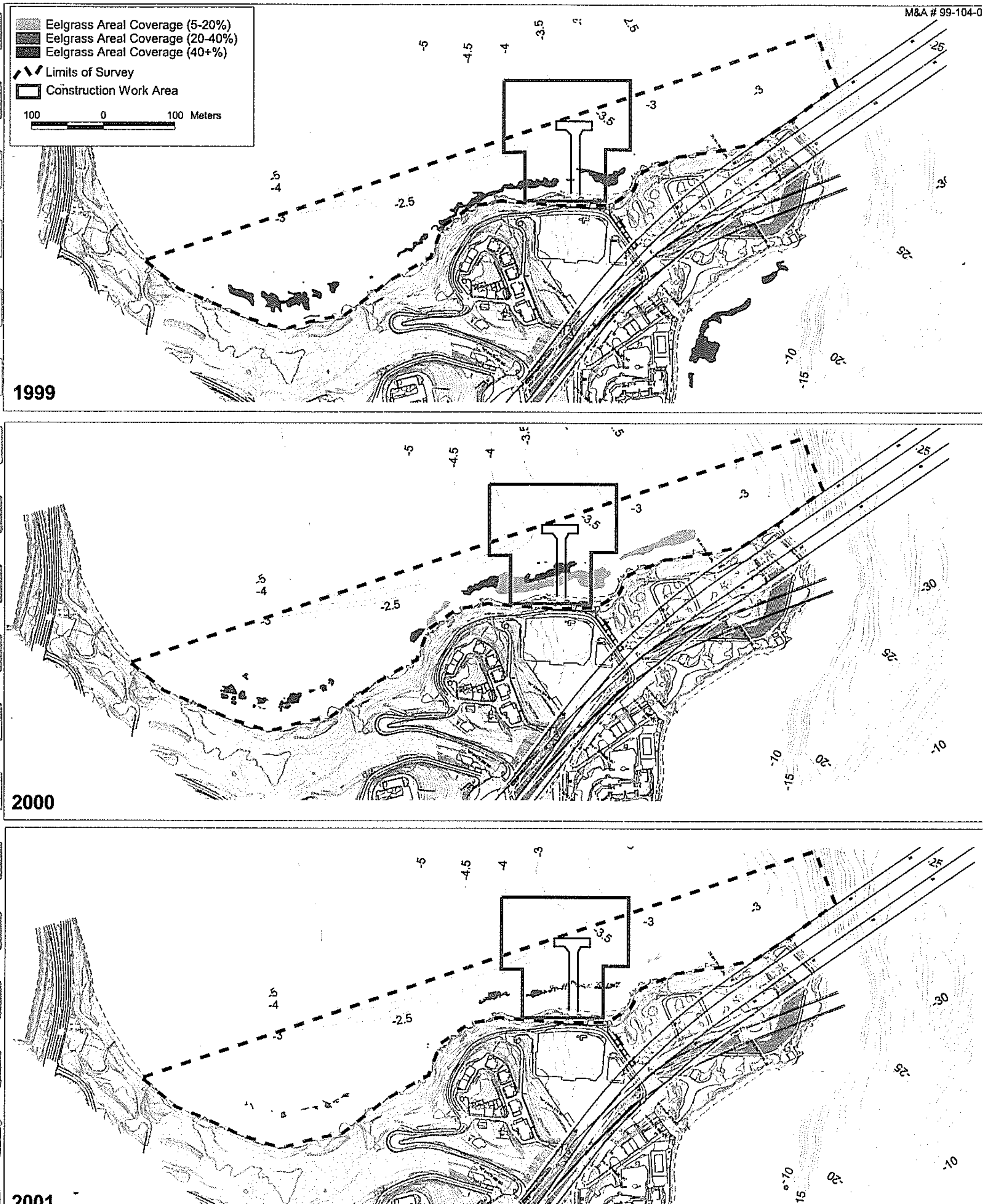

**San Francisco-Oakland Bay Bridge, East Span
Eelgrass Survey at Yerba Buena Island
1999-2001**

Figure 6

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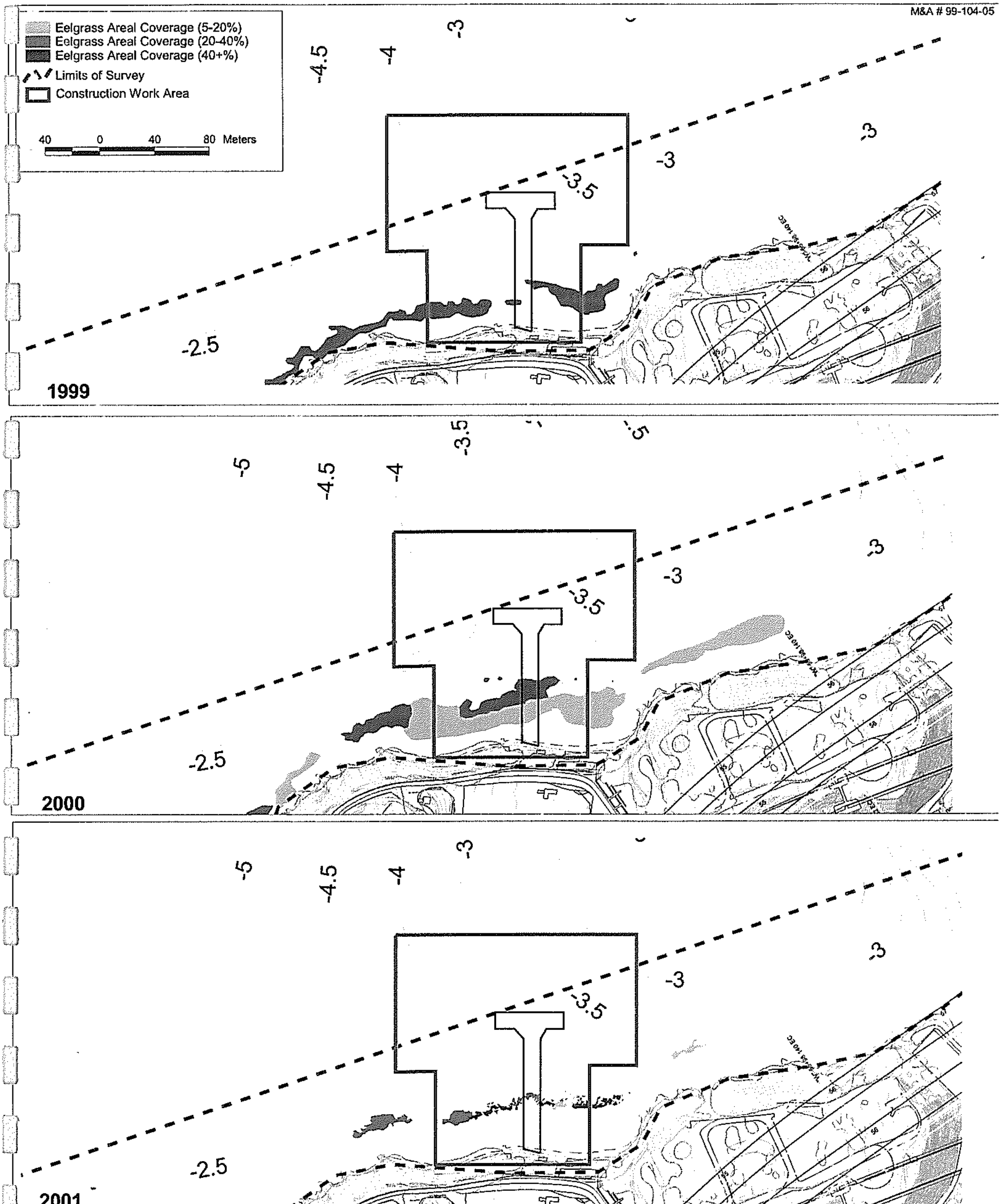

San Francisco-Oakland Bay Bridge, East Span
Eelgrass Survey at the Yerba Buena Island Construction Work Area
1999-2001

Figure 7

Merkel & Associates, Inc

Table 1 summarizes the areal coverage of eelgrass at each study site during the 1999, 2000, and 2001 survey years. Both total areal coverage and density of eelgrass areal coverage increased at the Emeryville Flats site between the 1999 and 2000 surveys. In 1999, 90% of total eelgrass within the Emeryville Flats site consisted of a bed with areal coverage density falling between 5-20% of total bottom area. In 2000, only 53% of the eelgrass within the Emeryville Flats site consisted of areal coverage density between 5-20%, while 41% contained areal coverage density of 20-40% (Table 1). Total eelgrass present in the Emeryville Flats study area increased by 7.3 hectares between 1999 and 2000. A similar increase in total coverage was observed at the Yerba Buena site, with total eelgrass coverage increasing by 0.3 hectares between 1999 and 2000.

Total eelgrass coverage did not change dramatically at the Emeryville Flats site between 2000 and the current, 2001 survey (Table 1). Similar to the 2000 survey, the 2001 survey revealed that 47% of eelgrass coverage at this site consisted of a bed with areal coverage density falling between 5-20%, while an additional 46% of total coverage had an areal coverage density of 20-40%. A similar pattern was not observed at the Yerba Buena Site. Total eelgrass coverage exhibited significant declines at this site between 2000 and 2001, and a larger percentage of eelgrass consisted of a lower areal coverage density.

Table 1 also addresses interannual change in cover within more focused project work areas. Changes within these smaller work area indicate a substantial increase in eelgrass cover between 1999 and 2000 followed by declines in eelgrass occurrence between 2000 and 2001. None of the observed changes in eelgrass coverage are particularly odd or unexpected for the study region.

Table 1. Eelgrass Bed Cover within SFOBB Study Areas

AREA	**1999**	**2000**	**2001**
(eelgrass cover)	**Eelgrass coverage in acres (hectares)**		
Emeryville Flats Study Area			
5-20%	15.8(6.4)	18.8(7.6)	16.8(6.8)
20-40%	0.5(0.2)	14.1(5.7)	16.8(6.8)
≥40%	0.7(0.3)	2.0(0.8)	1.8(0.7)
TOTAL	17.0(6.9)	34.8(14.1)	35.3(14.3)
Emeryville Flats Work Construction Area			
5-20%	0.5(0.2)	1.5(0.6)	1.0(0.4)
20-40%	1.5(0.2)	1.5(0.6)	0.7(0.3)
≥40%	0.0(0.0)	0.02(0.1)	0.5(0.2)
TOTAL	1.0(0.4)	3.2(1.3)	2.2(0.9)
Yerba Buena Study Area			
5-20%	0.0(0.0)	1.2(0.5)	0.1(0.04)
20-40%	1.2(0.5)	0.7(0.3)	0.2(0.1)
≥40%	0.0(0.0)	0.0(0.0)	0.1(0.04)
TOTAL	1.2(0.5)	2.0(0.8)	.5(0.2)
Yerba Buena Work Construction Area			
5-20%	0.0(0.0)	0.5(0.2)	0.0(0.0)
20-40%	0.2(0.1)	0.2(0.1)	0.1(0.04)
≥40%	0.0(0.0)	0.0(0.0)	0.0(0.0)
TOTAL	0.2(0.1)	0.7(0.3)	0.1(0.04)

3.2 Eelgrass Turion (Shoot) Density

Within the eelgrass patches, turion (leaf shoot) densities were found to be 31.77±25.30 turions/m^2 with a sample size of 71 in 1999, 37.6± 23.84 turions/m^2 with a sample size of 20 in 2000 and 35.2±44.2 turions/m^2 with a sample size of 20 in 2001. These low turion densities are fairly typical for eelgrass patches within the turbid waters of San Francisco Bay. The high standard deviations for each sample indicate the patchiness of the eelgrass beds, with multiple quadrat samples collected at each site resulting in turion counts of zero.

4.0 EELGRASS HABITAT CHANGE ANALYSES

From 1999 to 2000, an explosive increase in both eelgrass coverage and density occurred within the vicinity of the OTD study area. Eelgrass coverage and density did not, however, change dramatically between 2000 and 2001 at the Emeryville Flats study area. The dramatic increase in eelgrass between 1999 and 2000 had raised some question as to what the "normal" condition is for these eelgrass beds and even how such a dramatic change could occur within a single year. While it is not fully known what environmental changes had occurred between 1999 and 2000 to allow an expansion of eelgrass on the Emeryville Flats and within Clipper Cove, similar changes in eelgrass density were observed at Bayfarm Island during the same period (Merkel & Associates, unpub. data). During the period 2000 to 2001 when size and density of eelgrass beds remained relatively stable within the study area of the Emeryville Flats, the Clipper Cove eelgrass beds declined dramatically. Without more long-term data, a full analysis of the observed eelgrass dynamics was not possible. However, the following discussions on eelgrass dynamics might help elucidate the intermediate changes in the East Span Project study area. First, beds from other bays and estuaries in California have experienced similar dynamics in distribution and coverage. Also, the plant level and patch dynamics that affect large-scale changes between years are discussed.

4.1 Interannual Changes in Distribution and Bottom Coverage

It is important to recognize that most eelgrass is constantly in a state of flux responding to multiple environmental factors that are both highly predictable (seasonal cycles) as well as less predictable (interannual and episodic cycles). Within eelgrass beds under optimal conditions, extrinsic environmental influences result in less recognizable effects on the bed than are observed in marginal environments where minor changes in the environment may result in a substantial expansion or decline in eelgrass. The Emeryville Flats at the Oakland Touchdown area (and Clipper Cove at YBI) are considered marginal environments subject to significant variability in eelgrass coverage as a result of minor environmental flux.

The flux in eelgrass coverage and density observed between 1999 and 2000 is not atypical for marginal environments with very flat bathymetry. Minor improvements in light conditions can result in substantial increases in eelgrass density and coverage if eelgrass is near the photocompensation depth where photosynthesis balances metabolic demands. This is especially true where significant potential for expansion exists due to available habitat at or near the limits of eelgrass growth. One of the most notable features of the Emeryville Flats eelgrass bed is that the entire extent of the eelgrass beds mapped in this area in October 1999 occurred within a range of depths less than 3.3 feet (one meter). In contrast, eelgrass distribution in October 2000 and 2001 extended across depth ranges in excess of 5.6 feet (1.7 meters) and 4.9 feet (1.5 meters), respectively. This increased range observed in the latter two years of survey added substantially to the extent of eelgrass at deeper depths. As such, low density eelgrass extended across much of the bottom that previously did not support eelgrass while substantially increased eelgrass density occurred at higher elevations within the depth range that supported eelgrass in 1999.

The observed densities for eelgrass coverage at the SFOBB during all baseline survey years are fairly typical for eelgrass beds located along the eastern shore of San Francisco Bay. For these regions of the Bay, sparse eelgrass is the norm and the observed vegetative cover values compare favorably to those measured elsewhere. In October 1996 within Richmond Harbor, eelgrass vegetative coverage ranged from less than 5% to over 20% along the inside of the training jetty and north of Point Richmond (SAIC and Merkel & Associates 1997a). In October 1998, Richmond Harbor and Point Richmond continued to support eelgrass at comparable but somewhat reduced coverage ranging from less than 5% to between 16% and 20% (Merkel & Associates 1999a). By far, the greatest portion of these eelgrass beds fell at or below 5% vegetative cover during both 1996 and 1998. On Point Richmond in San Pablo Bay, eelgrass cover ranged between 0% and 25% with the mean cover being around 5% within Point Orient, Point Molate, and the San Pablo Shoal areas. The shallower and more sheltered portions of Point Molate supported eelgrass beds with a cover of 10% to 20% (SAIC and Merkel & Associates 1997b). In August 1997, an eelgrass survey was completed around the Richmond-San Rafael Bridge and eelgrass beds were found to range between 8% and 17% vegetative coverage for the area around the east end of the bridge (Merkel & Associates 1997). During this same study, within the Point Molate reference area, eelgrass coverage was determined to be 12%, a value that falls within the broader range determined for this site during prior investigations (SAIC and Merkel & Associates 1997b). In October 1999, the eelgrass coverage on Middle Harbor Shoal was determined to be 12% for this small bed (Merkel & Associates 1999b).

It is possible that the observed difference between 1999 and 2000/2001 is a manifestation of larger cyclic environmental influences. In southern California, eelgrass fluctuations amounting to declines of more than 70% beginning in October 1997 followed by recovery to greater than 100% of pre-existing beds by June 1999 were likely attributable to El Niño Southern Oscillation (ENSO) influences (Merkel & Associates 2000b). Changes in the environment during the 1998 ENSO within southern California were principally related to the effects of elevated sea levels and, to a lesser degree, increased run-off. Both of these influences worked to diminish light levels and caused precipitous die-off of eelgrass within marginal environments. While not proven, it is likely that similar ENSO phenomena have also influenced the structure of eelgrass within San Francisco Bay. This is not to say that such marginal environments would not be influenced by ordinary interannual climatic variability. In central California the extent of sea level rise during the recent ENSO was less than observed in southern California; however the sediment discharge from rivers was substantially greater. This is especially true within San Francisco Bay where substantial flood flows discharged through the Bay Delta region and local creeks adding to the resuspendable sediment loads on the Bay floor. Over time, suspendable surface sediments are slowly purged from the system leaving coarser, less mobile materials. While sediments are being suspended and exported, turbidity is increased and light penetration decreased resulting in a reduction in photosynthetic potential and a decline in eelgrass beds. Because the purging of sediments following episodic storms may require a number of years, eelgrass expansion from 1999 to 2000 and 2001 surveys may likely be a result of continued sediment flushing and an associated reduction in water turbidity following the severe storms of 1998. Such eelgrass expansions were observed in Southern California following the last ENSO as well as the prior 1987 and 1992 ENSOs.

4.2 EELGRASS PATCH DYNAMICS

Eelgrass patches are the basic building blocks that, in aggregate, make up the defined eelgrass beds. Eelgrass patches within the survey area appeared to be predominantly comprised of small- to medium-sized individual plants which have spread rhizomotously over the bottom and in some instances coalesced with other plants to form larger eelgrass stands. Both the number of patches and the degree of coalescence of patches was greater in 2000 and 2001 than in 1999.

The patchy distribution of eelgrass observed around the SFOBB East Span is fairly typical of San Francisco Bay and is termed a "leopard-spot" distribution pattern. This pattern is a result of environmental stresses that may vary unpredictably over time and lead to intermittent emergence or loss of eelgrass patches from an area over short periods of time (months to a few years). Typically, these dynamic eelgrass environments are strongly structured by recruitment of new plants and mortality of older plants. Sexual reproduction may account for a significant portion of the plant growth within the bed and thus beds may be fairly genetically diverse. For such areas, the size, shape, and density of eelgrass beds can be highly variable and indicative of the time between less favorable environmental conditions. The leopard-spot distribution pattern observed at the bridge is not unique to San Francisco Bay, but rather may be observed within marginal environments in other locations as well. Most typically, this pattern is observed along the deeper fringes of eelgrass beds where light limitations preclude eelgrass growth over portions of the year or intermittently between years but is adequate at some period to allow for seedling establishment and growth.

While leopard-spot distribution can emerge from either beds in expansion or decline, further information regarding the eelgrass bed may be revealed by more closely examining the shape and distribution patterns of individual patches. The derivation of eelgrass patches through the expansion of individual plants is suggested by very small patches of general radial symmetry as a recurrent pattern within the surveyed eelgrass beds (Figure 3). This pattern of patch development is also indicative of highly dynamic systems comprised principally of recently recruited seedling plants rather than senescent or weathered older plants. Individual plants typically expand radially when not affected by neighboring plants but generally suffer non-symmetric partial mortality and coalescence of patches as eelgrass beds mature. These forces erode the radial symmetry of individual plants and generate patches with uneven shapes and densities, generally comprised of larger blotched pattern growth.

In all three surveys, eelgrass beds were dominated by small symmetric patches. This suggests a bed that is dominated by seedling recruitment and a high degree of annualism in which many of the plants die off completely or nearly so each year and are replaced by new seedling growth during the following year. Such beds exhibit high year-to-year variability in density and patch distribution and are controlled by factors of seed production, seedling establishment, water clarity, storm intensity, tidal circulation patterns and even bioturbation (biological disturbances).

Most of the patches of eelgrass observed on the Emeryville Flats were less than 3.3 feet (one meter) in diameter when examined by divers. In the warmer waters of southern California, eelgrass may expand vegetatively at a rate in excess of 0.5 inches/day (1.2 cm/day) (unpublished data, 1987 Mission Bay, San Diego, CA). If vegetative expansion in the colder and more light limited waters of San Francisco Bay were only one quarter of that observed in southern California, a single seedling could attain a coverage in excess of 10 ft^2 (one m^2) in less than 6 months. At the rate of expansion observed in southern California, a seedling could expand to 10 ft^2 (one m^2) coverage in about 1.5

months, although shoot density within such plots is generally quite sparse. While there is a severe paucity of information regarding the general distribution and dynamics of eelgrass within San Francisco Bay, it is not surprising to see significant changes in eelgrass bed character from one year to the next given information available from other areas.

In all three surveys, portions of the beds exhibited some coalescence of patches and the formation of patches that are clearly comprised of multiple plants rather than single individuals (Figure 3). During these surveys, the largest most coalesced patches of eelgrass occurred on the high points of sandy shoals located on the Emeryville Flats. Other relatively large coalesced beds occurred within Clipper Cove on a narrow band of silty sands adjacent to the deeper navigational basin.

While the rate of change observed at the Emeryville Flats is not dissimilar from that recorded in other systems with a substantial seedling recruitment component, it is difficult to conclude anything relative to other San Francisco Bay eelgrass beds. No long-term data collection has been done to document the degree of interannual flux that would normally be anticipated within San Francisco eelgrass beds. What has been observed at Bayfarm Island, Richmond Harbor, and Point Molate suggests that San Francisco eelgrass is capable of substantial expansion and contraction over time; however, it would be inappropriate to attempt to quantify maximum rates of change absent more directed efforts.

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