Determination of the extent and type of injury to rocky intertidal algae and animals one year after the initial spill (Cosco Busan): a report prepared for OSPR (California Fish and Game)

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Tier II General Objectives

- *DETERMINE EXTENT AND TYPE OF INJURY TO ROCKY INTERTIDAL ALGAE AND ANIMALS ONE YEAR AFTER THE INITIAL SPILL*

OUTER COAST AND ALCATRAZ

1. What is the natural variability in the cover of dominant algal taxa for select long-term monitoring sites (NOAA and NPS) within the incident area?
2. Is there is a significant difference in the spatial distribution and cover of dominant algal taxa at long-term monitoring sites and amongst long-term monitoring sites post-spill?
3. Can the magnitude and type of differences in algal cover be associated with the degree of shoreline oiling?
4. Is there a difference in taxa richness and distribution at Alcatraz Island prior to and after the spill? If so, can this difference be explained by regional trends at nearby biodiversity sampling sites?
5. For Alcatraz, can the magnitude and type of differences be associated with plots with varying degrees of oiling?
6. Have motile invertebrate abundances declined at oiled sites (or as a function of degree of oiling?

IN-BAY SITES

1. Is there a significant difference in the cover of dominant algal taxa between in-Bay rock riprap sites at various degrees of shoreline oiling (no oil observed, very light-light, moderate, heavy) and intensive cleaning.
2. Is there a significant difference in the size class distribution of *Fucus* or other rockweeds between in-Bay rock riprap sites at various degrees of shoreline oiling and intensive cleaning?
3. Do mussels on-top of and within riprap interstices still contain measurable amounts of Cosco Busan oil within their tissues? Is this difference associated with various degrees of shoreline oiling? Is the degree of oiling related to position, i.e., those from within the interstices vs. those outside the interstices? (these data and results will be presented in a separate report)
4. Is there a difference in shore crab densities (or size class distribution) between in-Bay rock riprap sites at various degrees of shoreline oiling and intensive cleaning? This analysis is part of the analysis that included mobile invertebrates.
5. Is there a significant difference in the abundance of motile invertebrates between in-Bay rock riprap sites at various degrees of shoreline oiling and intensive cleaning? This analysis is part of the analysis that included mobile invertebrates.
6. Is there a difference in limpet size class categories (<5 mm, 5-15mm, >15mm) between in-Bay rock riprap sites at various degrees of shoreline oiling and intensive cleaning? This analysis is part of the analysis that included mobile invertebrates.

Structure of the Report

This report is divided into three sections: Assessment, Appendix 1 and Appendix 2. The Assessment section is the main portion of the report and discusses the methods and results of sampling and analyses done to assess the impact of the Cosco Busan Oil Spill on rocky intertidal communities that were affected by the spill. In Appendix 1 we present the characteristics of the sites assessed in section 1. Appendix 2 is mainly a collection of photographs that provide a context for some of the sampling and assessment done in Section 1. Importantly some of the photos in Appendix 2 provide additional information for locations where or times when quantitative data were unavailable. For example, we have time series photos at Point Blunt and Berkeley Marina. This is important as we were prevented from sampling at these sites until after cleaning had occurred, and these photos during the spill at Point Blunt provide information on the structure of the community pre-cleaning. Similarly photos taken at Berkeley Marina, prior to the spill provide an idea of the biological community prior to the spill and subsequent cleaning.

Assessment - Methods

The sites sampled fall into two main categories, outer coast sites and in-Bay sites (see Appendix for maps and photos). Outer coast and in-Bay sites were approached separately because they are unique habitats. Alcatraz, although in-Bay, exhibits a habitat more similar to outer coast sites than in-Bay sites and so it will be considered an outer coast site here.

Zonation

Because of the gradient of tidal exposure, intertidal areas have strong species zonation patterns. Often this gradient is divided into three zones: high, medium low (see Figure 1). Our surveys were designed to sample the areas so that all three zones were evaluated (tides permitting). We took two specific approaches to sampling based on whether the intertidal area was broad with a low slope (e.g. Fitzgerald) or narrow with an extreme slope (e.g. most riprap areas). For broad areas we used a series or transects that were perpendicular to the water's edge, whereas for narrow areas we used transects parallel to water's edge. The perpendicular transects traversed the zonation at each site. The parallel transects were positioned in each of the three zones (low, mid high) where possible (see additional explanation of methods below).

Outer Coast

To determine the extent and type of injury to rocky intertidal organisms on the outer coast approximately one year after the initial spill, four sites representing different levels of oiling (according to SCAT survey data) were chosen (Table 1). Alcatraz (SCAT segment SFH001), which had heavy oiling, and Bolinas (SCAT segment MRL002C), which had very light-light oiling, are long term biodiversity monitoring sites for which pre-spill data are available. Both sites were also visited shortly after the spill. Because of these data, these sites can also be used as pre-spill reference sites. Fitzgerald (SCAT segment SML005A), which had very light-light oiling, and Linda Mar (SCAT segment SMK005), which had no oil observed, are sites that were sampled immediately following the spill. The biodiversity transect grids were located and used in the sampling of the long term monitoring sites (Alcatraz and Bolinas). Note – biodiversity sampling utilizes sampling in the field rather than photo-sampling (see specific approach in http://cbsurveys.ucsc.edu/). A biodiversity style transect grid (see Figure 1 and photos in Appendix 1) was used to sample Fitzgerald and Linda Mar both immediately following the spill and during the Tier II study. To set up a biodiversity transect grid, a base transect was laid out parallel to shore at or just above the intertidal biology. At some interval along this baseline transect, transects were laid out perpendicular to the baseline transect and extended from the baseline transect to the waters edge. A lower baseline was used to ensure that the perpendicular sampling transects remained straight and at an equal distance from each other. Since Linda Mar was photo sampled in November 2007 following the Cosco Busan oil spill, we approximated the same position of the transect grid using GPS coordinates and compass bearing information recorded during the original sampling. Fitzgerald was also photo sampled shortly after the Cosco Busan spill. We approximated the same position of the transect grid using marine epoxy markers left by the previous samplers as well as photos, GPS coordinates and compass bearings recorded during the original sampling. By doing this we were able to closely approximate the transects originally sampled and sample them again during the Tier II study.

Algal Taxa

Long-term biodiversity data from the CBS (Coastal Biodiversity Survey) and community structure data from the MARINe (Multi-Agency Rocky Intertidal Network) surveys were used to estimate natural variability in the cover of dominant algal taxa for select long-term monitoring sites. Alcatraz and Bolinas were sampled using biodiversity protocols (http://cbsurveys.ucsc.edu/sampling/sampling.html) to determine if there is a significant difference in the spatial distribution and cover of dominant algal taxa at and amongst long-term monitoring sites post-spill.

To determine if the magnitude and type of differences in algal cover can be associated with the degree of shoreline oiling (no oil observed, very light-light, moderate, heavy), an approach based on trends in algal cover associated with differences in degree of oiling among sites was used. Using a point contact method, the species first encountered directly under a specific point at a set interval along each perpendicular transect was recorded. The point contact interval was chosen taking into account the length of each transect so that the total number of points recorded at each site would be approximately 500. This number varied slightly because the transect lengths varied among sites and the interval was chosen so that the sampler would have fewer calculations in the field (Table 2).

Taxa Richness

To determine if there is a difference in taxa richness and distribution at Alcatraz Island prior to and after the spill, Alcatraz was revisited and resampled using biodiversity protocols (http://cbsurveys.ucsc.edu/sampling/sampling.html). Generated georeferenced species data were compared to pre-spill data. Quadrat photos taken shortly after the spill were retaken during the Tier II study. Photos were scored digitally in Photoshop. A grid with 100 points was laid over the photo so that the area inside the quadrat could be scored for 100 points. Comparisons between species assemblages at the time of the spill and post-spill were then made to determine if there were differences. In order to determine if any differences between pre-spill and post-spill can be explained by regional trends at nearby biodiversity sampling sites, biodiversity data from other long term monitoring sites as well as data from photo scoring were used to assess levels of variability at non-spill sites.

Invertebrate Taxa

To assess if motile invertebrate abundance was affected at oiled sites (or as a function of degree of oiling), abundance and natural spatial variability in abundance of motile invertebrates at long term monitoring reference sites were assessed. Alcatraz, Bolinas, Fitzgerald and Linda Mar were then sampled for motile invertebrate abundance.

At each site, the same baseline and perpendicular transects described above were used. Perpendicular transects were divided into high, mid and low intertidal zones. The distance along transects and within each zone where sampling occurred was selected randomly on site using a random number generating sheet. A 50cm x 50cm quadrat was placed at the designated distance along the transect and all motile invertebrates within the quadrat were identified and counted.

Shore crabs and seastars were counted at each site so that comparisons could be made to counts taken during the spill as well as among sites with varying degrees of shoreline oiling. Areas that provided suitable habitat for shore crabs were located at each site and timed searches were conducted. If one sampler was searching, the search time was 10 minutes, if two samplers were searching the search time was 5 minutes so that the searching effort remained constant. Shore crabs found during the timed search were identified and counted. The same was done for sampling seastars.

In-Bay

To determine the extent and type of injury to rocky intertidal algae and animals within the bay approximately one year after the initial spill, thirteen sites (see Appendix 1) representing different substrates (bedrock, riprap or boulders), degrees of shoreline oiling during the spill (no oil observed, very light-light, moderate, heavy) and cleaning intensity were chosen according to SCAT survey data (Table 1). Sites were selected to include a minimum of one each for no observed oiling and very light-light oiling and two sites each for moderate oiling and heavy oiling as well as for intensive cleaning (i.e. power washing or *Fucus* removal). The transect setup used for sampling varied among sites depending on two conditions: 1) whether or not the site was sampled during the spill and 2) the steepness of the intertidal zone to be sampled. If the site was sampled during the spill, the original transects were located using GPS coordinates, photos, and/or marine epoxy markers left during the original Tier I sampling in 2007. The original transects used during the spill were then used again for the Tier II study. If the site was not sampled during the spill the transect setup varied with the steepness of the site. At sites that were so steep as to make the distance from the high zone to the low zone too small for a biodiversity style setup (as used at outer coast sites), transects were run parallel to shore so that the different zones were represented. This was the case at sites with a riprap substrate. If the distance between the high and low zone was great enough to allow it, a high zone transect, a low zone transect and a mid zone transect was run. If not, then a high zone and low zone transect was run. The length of transects varied among sites (Table 2). For example, at Golden Gate Fields South (SCAT segment ALA005) the area to be sampled would only accommodate a 23m transect. Transect lengths were assigned to well represent the site. For sites that were sampled during the spill the same transect lengths were used. The biodiversity style transect setup used on the outer coast was only used at one site within the bay, Point Blunt (SCAT segment MRR001) on Angel Island. The substrate and slope of the intertidal at this site more closely resembled an outer coast site and was unlike any other site within the bay with regard to substrate and slope. The transects at Point Isabel were slightly different from the other sites because the shoreline there is long and is not homogenous. At this site, six transects were run alternating high zone and low zone (although many of the low zone transects represented the mid zone) along the shoreline so that the whole site could be represented.

Algal Taxa

To determine if there is a significant difference in the cover of dominant algal taxa among in-Bay rock riprap sites at various degrees of shoreline oiling (no oil observed, very light-light, moderate, heavy) and intensive cleaning, the point contact method described for the outer coast was used. Sites with transects running parallel to the shoreline were sampled in the same way that perpendicular transects on the outer coast were sampled. The point contact interval was chosen taking into account the length of each transect so that the total number of points recorded at each site would be approximately 500. This number varied slightly because the interval was chosen so that the sampler would have fewer calculations in the field (Table 2). The idea was to use an approach based on trends in algal cover associated with differences in degree of shoreline oiling, substrate type, and cleaning intensity among sites.

To assess if there is a significant difference in the size class distribution of *Fucus gardneri* or other rockweeds among in-Bay rock riprap sites at various degrees of shoreline oiling and intensive cleaning, a transect was sampled for *F. gardneri* at each site *F. gardneri* was present. At sites with no *F. gardneri* no other rockweeds were found. The transect length varied from site to site depending on the density of *F. gardneri* at the site and the size of the site (Table 2). Transect lengths were assigned so that, if possible, 100 individuals could be measured along each transect. A 1m pole (made from PVC) was placed along the transect at intervals so that 10 *F. gardneri* individuals along the pole could be measured at 10 different distances along the transect. Individuals were randomly selected and measured along the pole. Each individual was measured from the base of the holdfast to the end of the longest blade so that the length of each individual could be recorded. In this way 100 individuals could be measured along each transect. At sites where *F. gardneri* was rare, less than 100 individuals were measured (Table 2). *F. gardneri* was also sampled at the outer coast sites for further comparison (Table 2).

Invertebrate Taxa

Mussels were collected in order to determine if they still contain measurable amounts of Cosco Busan oil within their tissues. They were collected from sites with different degrees of shoreline oiling to assess if there is an association between the degree of shoreline oiling and whether or not the mussels have Cosco Busan oil within their tissues. The mussels collected were either one of three species, *Mytilus californianus, Mytilus trossulus* or *Mytilus galloprovincialis* , depending on which species was present at each site. The sampler wore Nitrile gloves when detaching mussels from the substrate to avoid contaminating the tissue. The mussels were then securely wrapped in aluminum foil (against the dull side) and placed in a plastic zip lock bag that was then wrapped in paper tape and placed within another plastic zip lock bag. The secondary bag also contained a Chain of Custody form (COC) and slips of paper with collection information on them including the SCAT section ID and the latitude and longitude of the collection site (recorded from the GPS unit that was carried on site). Mussels were collected from on top of riprap and within the interstices of riprap when possible to determine if the degree of oiling is related to position (Table 3). Mussels were also collected at outer coast sites (Table 3). After they were collected they were transported in coolers packed with ice to UCSC where they were stored in a freezer at -20˚C until they were shipped.

All samples remained in their original bags with their respective COC and sample ID forms and were placed in a single container packed with dry ice for shipment on the morning they were shipped. They were shipped Fed Ex priority overnight express and arrived at Alpha Analytical Woods Hole Labs for chemical analysis the following morning.

Shore crabs were counted at each site so that comparisons could be made to counts taken during the spill as well as among sites with varying degrees of shoreline oiling and cleaning intensity. Searches were conducted within the bay in the same way they were conducted at outer coast sites. Seastars were counted in the same way when they were present.

To determine if there is a significant difference in the abundance of motile invertebrates among in-Bay rock riprap sites at various degrees of shoreline oiling and cleaning intensity the same methods were used as were used on the outer coast. The samples were divided up so that each zone was weighted equally (Table 2). If there was only a high and low transect then the mid zone counts were made either below the high transect or above the low transect depending on which better represented the mid zone. High zone counts were made with the quadrat placed above the high zone transect and low zone counts were made with the quadrat placed below the low zone transect. Within the 50cm x 50cm motile quadrats, limpets were classed according to size (<5mm, 5-15mm, >15mm) to assess any difference among sites with various degrees of shoreline oiling and cleaning intensity. The same was done on the outer coast so that further comparisons could be made among sites.

Community Structure

To assess any significant difference in a community within a site along a time scale, the original photos taken following the spill were assessed. Photos were categorized as “good” or “bad” based on the value of the photo for identification of species. Sites with a reasonable number of good photos where the exact photo could be taken again were revisited and photographed again. These sites were; Berkeley Marina West (SCAT segment ALA011A), Point Isabel (SCAT segment CCZ025) and Marina Green (SCAT segment SFH011). Photos were scored digitally in Photoshop. A grid with 100 points was laid over the photo so that the area inside the quadrat could be scored for 100 points. The first species hit under each point was recorded. Comparisons between species assemblages at the time of the spill and post-spill were then made to determine if there are differences and if they are related to the degree of shoreline oiling and/or cleaning intensity.

Sites Sampled Breakdown for Tier II Rocky Intertidal Studies

Inner Bay Sites

Site Code and Name	Latitude and Longitude	Substrate	Level of Oiling	Power Washed	*Fucus* Removal
ALA003 Golden Gate Fields North	37.88933˚N, -122.31825˚W	Rip-Rap	Moderate	No	Unknown
ALA005 Golden Gate Fields South	37.88577˚N, -122.31644˚W	Rip-Rap	Heavy	No	Unknown
ALA011C Berkeley Marina West	37.86168˚N, -122.31577˚W	Boulders	Light/Very Light	No	Unknown
ALA011C Berkeley Marina East	37.86267˚N, -122.31458˚W	Rip-Rap	Moderate	Yes	Unknown
CCZ025 Point Isabel	37.89748˚N, -122.32448˚W	Rip-Rap	Heavy	Yes	Unknown
MRS005 Tiburon Yacht Club	37.91674˚N, -122.47495˚W	Rip-Rap	No observed oil	No	Unknown
MRR001 Point Blunt (Angel Island)	37.85285˚N, -122.41870˚W	Bedrock	Heavy	No	Yes
MRR008A China Cove West (Angel Island)	37.87061˚N, -122.42737˚W	Boulders	Light/Very Light	No	Unknown
MRR008C China Cove East (Angel Island)	37.87052˚N, -122.42561˚W	Bedrock	Light/Very Light	No	Unknown
SFF004 Treasure Island	37.82071˚N, -122.37511˚W	Rip-Rap	Moderate	Yes	Unknown
SFF007 Yerba Buena Island	37.81158˚N, -122.36109˚W	Rip-Rap	Light/Very Light	No	Unknown
SFH010 Marina Green	37.80494˚N, -122.46223˚W	Rip-Rap	Light/Very Light	No	Unknown
SFH011 Marina Green	37.80805˚N, -122.44208˚W	Rip-Rap	Light/Very Light	No	Unknown

Outer Bay Sites

Site Code and Name	Latitude and Longitude	Substrate	Level of Oiling	Power Washed	*Fucus* Removal
MRL002C Bolinas (long term monitoring)	37.90430˚N, -122.72713˚W	Bedrock	Light/Very Light	No	Unknown
SFH001 Alcatraz (long term monitoring)	37.82513˚N, -122.42207˚W	Bedrock	Heavy	No	Unknown
SMK005 Linda Mar	37.60424˚N, -122.49983˚W	Bedrock	No observed oil	No	Unknown
SML005A Fitzgerald	37.51694˚N, -122.51325˚W	Bedrock	Light/Very Light	No	Unknown

Table 1: Sites sampled for Tier II Rocky Intertidal Studies. Inner and outer bay sites are represented and broken down by site name, latitude and longitude in decimal degrees, substrate type, level of oiling and type/intensity of cleaning. If there is long term monitoring at a site it is indicated next to the site name.

Site	Sample Type	Transect type	Number of Transects	Baseline Transect	Length	Number of Samples
Alcatraz	Point Contacts	Perpendicular	11	32	11	495
Alcatraz	Motile invertebrates	Perpendicular	7	32	11	21
Alcatraz	*Fucus gardneri*	Parallel	1	NA	20	100
Alcatraz	Photo	Perpendicular	NA	NA	11	30
Bolinas	Point Contacts	Perpendicular	5	30	171	575
Bolinas	Motile invertebrates	Perpendicular	5	30	171	15
Bolinas	*Fucus gardneri*	Parallel	1	NA	50	100
Bolinas	Photo	Perpendicular	NA	NA	171	64
Linda Mar	Point Contacts	Perpendicular	11	30	24	535
Linda Mar	Motile invertebrates	Perpendicular	6	30	24	18
Linda Mar	Photo	Perpendicular	NA	NA	24	138
Fitzgerald	Point Contacts	Perpendicular	8	35	80	433
Fitzgerald	Motile invertebrates	Perpendicular	5	35	80	15
Fitzgerald	*Fucus gardneri*	Parallel	1	NA	30	100
Fitzgerald	Photo	Perpendicular	NA	NA	80	74
Golden Gate Fields North	Point Contacts	Parallel	3	NA	45	540
Golden Gate Fields North	Motile invertebrates	Parallel	3	NA	45	15
Golden Gate Fields North	*Fucus gardneri*	Parallel	1	NA	20	100
Golden Gate Fields North	Photo	Parallel	NA	NA	45	32
Golden Gate Fields South 1	Point Contacts	Parallel	4	NA	23	225
Golden Gate Fields South 1	Motile invertebrates	Parallel	4	NA	23	9
Golden Gate Fields South 1	*Fucus gardneri*	Parallel	1	NA	15	50
Golden Gate Fields South 1	Photo	Parallel	NA	NA	23	18
Golden Gate Fields South 2	Point Contacts	Parallel	4	NA	23	225
Golden Gate Fields South 2	Motile invertebrates	Parallel	4	NA	23	9
Golden Gate Fields South 2	*Fucus gardneri*	Parallel	1	NA	15	50
Golden Gate Fields South 2	Photo	Parallel	NA	NA	23	18
Berkeley Marina East	Point Contacts	Parallel	3	NA	30	450
Berkeley Marina East	*Fucus gardneri*	Parallel	1	NA	80	100
Berkeley Marina West	Point Contacts	Parallel	3	NA	80	480
Berkeley Marina West	Motile invertebrates	Parallel	3	NA	80	15
Berkeley Marina West	Photo	Parallel	NA	NA	80	45
Point Isabel	Point Contacts	Parallel	6	NA	45	600
Point Isabel	Motile invertebrates	Parallel	6	NA	45	18
Point Isabel	*Fucus gardneri*	Parallel	1	NA	30	23
Point Isabel	Photo	Parallel	NA	NA	45	NA
Tiburon Yacht Club	Point Contacts	Parallel	2	NA	50	500
Tiburon Yacht Club	Motile invertebrates	Parallel	3	NA	50	15
Tiburon Yacht Club	*Fucus gardneri*	Parallel	1	NA	20	100
Tiburon Yacht Club	Photo	Parallel	NA	NA	50	33
Point Blunt	Point Contacts	Perpendicular	11	30	25	534
Point Blunt	Motile invertebrates	Perpendicular	6	30	25	18
Point Blunt	*Fucus gardneri*	Parallel	1	30	30	100
Point Blunt	Photo	Parallel	NA	NA	25	86
China Cove East	Point Contacts	Parallel	2	NA	42	327
China Cove East	Motile invertebrates	Parallel	2	NA	42	14
China Cove East	*Fucus gardneri*	Parallel	1	NA	26	100
China Cove East	Photo	Parallel	NA	NA	42	72
China Cove West	Point Contacts	Parallel	2	NA	47	371
China Cove West	Motile invertebrates	Parallel	2	NA	47	14
China Cove West	*Fucus gardneri*	Parallel	1	NA	19	100
China Cove West	Photo	Parallel	NA	NA	47	65
Treasure Island	Point Contacts	Parallel	2	NA	50	500
Treasure Island	Motile invertebrates	Parallel	2	NA	50	33
Treasure Island	Photo	Parallel	NA	NA	50	NA
Yerba Buena Island	Point Contacts	Parallel	2	NA	45	541
Yerba Buena Island	Motile invertebrates	Parallel	2	NA	45	15
Yerba Buena Island	*Fucus gardneri*	Parallel	1	NA	20	100
Yerba Buena Island	Photo	Parallel	NA	NA	45	32
Marina Green SFH010	Point Contacts	Parallel	2	NA	30	600
Marina Green SFH010	Motile invertebrates	Parallel	1	NA	30	7
Marina Green SFH010	Photo	Parallel	NA	NA	30	5
Marina Green SFH011	Point Contacts	Parallel	2	NA	30	600
Marina Green SFH011	Motile invertebrates	Parallel	2	NA	30	14
Marina Green SFH011	Photo	Parallel	NA	NA	30	18

Table 2: Site designates the site sampled. Sampling type denotes the type of sampling done at the site. Transect type denotes whether it was a parallel transect run along shore or a perpendicular transect running from the shore to the waters edge. The number of transects and the length of the baseline transects is also noted. The length of the sampling transects are averaged between lengths of all sampled transects at the site. The number of points, individuals or samples is denoted in the number of samples column.

Site	Number of mussels	Species	Top/Interstices
Marina Green SFH011	10	*Mytilus californianus*	top
Marina Green SFH011	10	*Mytilus californianus*	interstices
Pt. Isabel CCZ025	10	*Mytilus trossulus/galloprovincialis*	top
Pt. Isabel CCZ025	10	*Mytilus trossulus/galloprovincialis*	interstices
Alcatraz SFH001	6	*Mytilus californianus*	NA
Berkeley Marina East ALA011C	10	*Mytilus trossulus/galloprovincialis*	interstices
Berkeley Marina East ALA011C	10	*Mytilus trossulus/galloprovincialis*	top
Golden Gate Fields South ALA005	10	*Mytilus trossulus/galloprovincialis*	NA
Golden Gate Fields North ALA003	10	*Mytilus trossulus/galloprovincialis*	NA
Bolinas MRL002C	10	*Mytilus californianus*	NA
Treasure Island SFF004	b/w 8 and 10	*Mytilus californianus*	NA
Pt. Blunt MRR001	5	*Mytilus californianus*	NA
Linda Mar SMK005	10	*Mytilus californianus*	NA

Table 3: The site, number of mussels, species of mussel collected and whether it was collected on top of or in the interstices of riprap. NA is indicated either when the substrate was not riprap or at riprap areas when mussels only occurred on tops of surfaces.

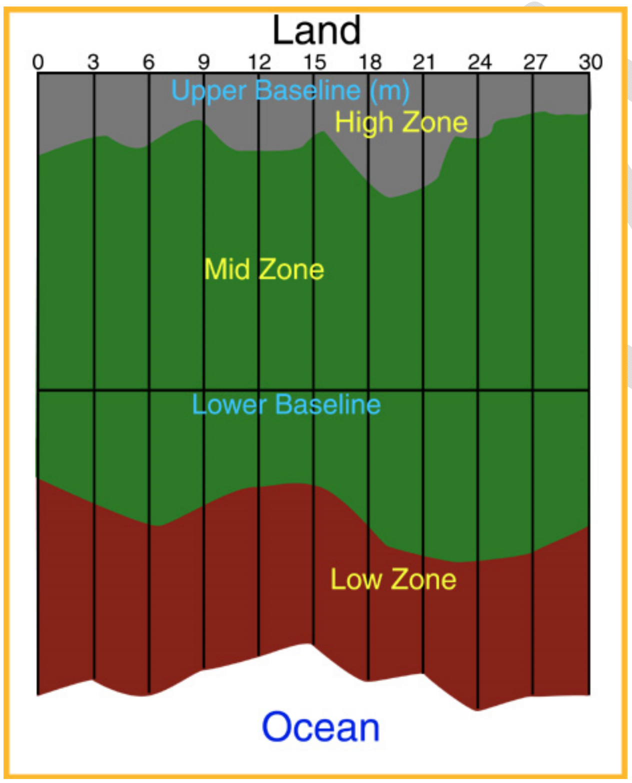


Figure 1: Diagram of biodiversity style transect grid showing the upper baseline transect and lower baseline transect with perpendicular sampling transects running from the upper baseline transect through the lower baseline transect.
Adapted from: http://cbsurveys.ucsc.edu/sampling/sitesetup.html

Analytical Methods and Results

Two broad types of analysis (across location, within location) were done to investigate species composition and abundances at a series of locations in the bay and outside of it. Each site was characterized (see above) using the SCAT degree of oiling categories: no oil observed, very light-light, moderate, heavy. In addition, whether the site was power washed of had algal cutting was noted. The first approach (across location) was to determine if the species composition could be distinguished simply as a function of oiling or type of cleaning (after controlling for other factors such as substrate type). Here locations were considered to be replicates. This approach was used because of the limitations on the use of the second approach (within location), which relies on determining if there was an impact within a given location. Whereas the across location approach relies on replication in space (e.g. multiple oiled sites), the within location approach, while more precise, relies on an understanding of the change in species composition from a period prior to the oil spill – relative to a control situation. This approach therefore relies on the existence of data collected prior to the impact. Such data are rare in the Bay.

Assessment across locations – Species Composition

The data evaluated in this section all come from the Biodiversity style sampling approach discussed above. This approach relies on spatial contrasts to point to particular mechanisms that could affect species composition. In this study we evaluated the contributions of substrate type, degree of oiling and whether the site had been power-washed or not. The statistical underpinnings are based on Bray-Curtis similarity values along with a resampling algorithm to produce probability values. Visually the results are depicted as cluster analyses. Each branch in the cluster is assessed for its separation from the nearest other branch. Branches that differ at $P<0.05$ are shown in the figures below. It is important to note that the spatial distributions of the potential mechanisms are not balanced – that is the spatial organization of the mechanisms of interest is not like you would hope for in an experimental design. For example, oiling level was not random allocated across locations. Hence traditional statistical approaches are inappropriate as they rely on the underlying assumptions of independence, identical distributions and representation that can most generally be obtained from random allocation of replicate locations – which clearly is not the situation here. Instead, the approach utilized in this section is to look for patterns in the results that consistently point to specific mechanisms.

Both sessile and motile species composition was evaluated (Table 4). The figures below show the results. Lines in red indicate locations that do not differ at $P<0.05$, while those in black indicate separation at $P<0.05$. There would be support for a particular mechanism affecting species composition if all sites having a particular level of a factor clustered together. As shown in Figures 2-7 the key result from this analysis (which was for the period up to 1.5 years post-spill) is that there is no strong support for a general (across location) effect that is attributable to oiling or the post-oiling cleanup.

Motile Species	Point Intercept taxa or substrate	
Tegula funebralis	Acanthina	Mytilus trossulus
Pagurus	Anthopleura xantho.	Non-coralline crust
Pachygrapsus crassipes	Anthopluera eleg.	Odonthalia
Lottia gigantea	Anthopluera sola	Oil/tar
Large Limpets 15mm	Articulated coralline	Other Brown
Med Limpets 5-15mm	Balanus	Other Green
Small Limpets 5mm	Blue-green algae	Other Red
Littorines	Bryozoan	Oyster
Hemigrapsus	Chthamalus	Pelvetiopsis
Acanthina	Corraline crust	Phyllospadix
Chitons	Diatom Scum	Phragmatopoma
Nucella	Dead Balanus	Porphyra
Cancer crabs	Dead Chthamalus	Pollicipes
Lacuna	Drift	Prionitis
Bittium	Endocladia	Red Turf
Searlesia	Egregia	rock
Strong. purpuratus	Filamentous algae	Sand
Margarites pupillus	Fucus	Shell Debris
Pisaster	Gravel	Silvetia
Ocenebra	Limpet	sponge
Tegula brunea	Lottia gigantea	Terrestrial Grass
	Mud	Tegula
	Mastocarpus	Trash
	Mazaella	Unidentified Tube Worm
	Mytilus californianus	Ulva/Enteromorpha
		Verrucaria

Table 4: List of taxa and substrate sampled in the motile or Point Intercept Surveys

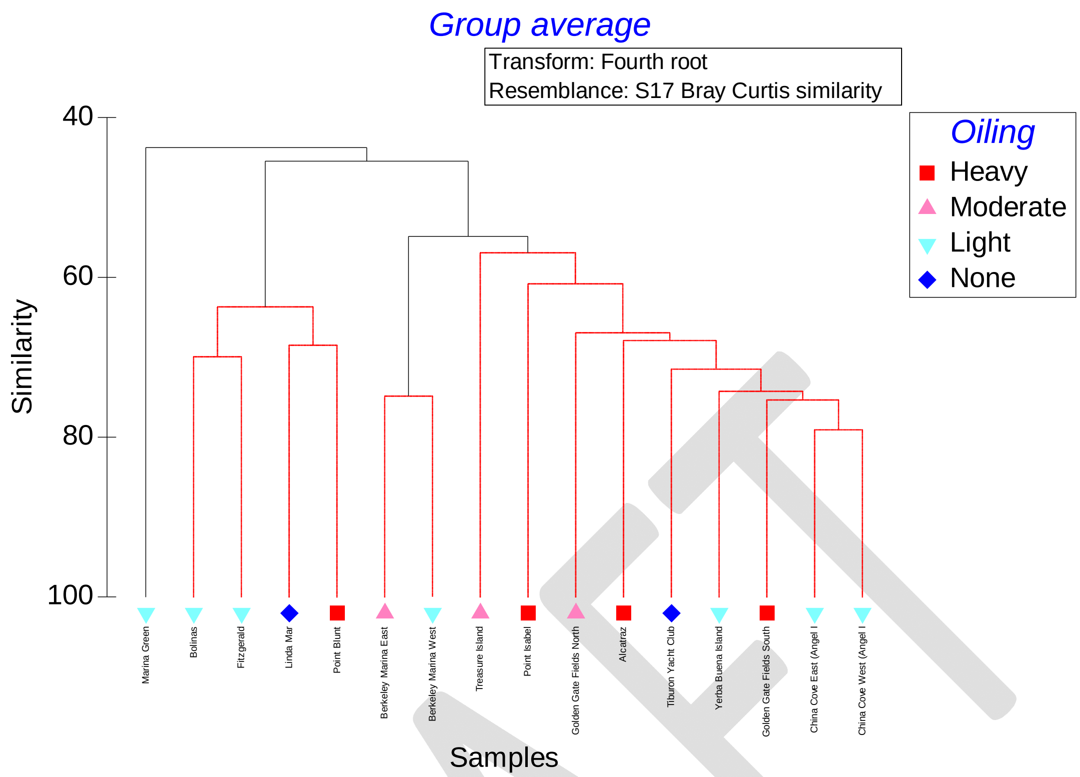


Figure 2: Cluster analysis for point intercept data: Symbols represent level of oiling (light and very light were combined for this figure).

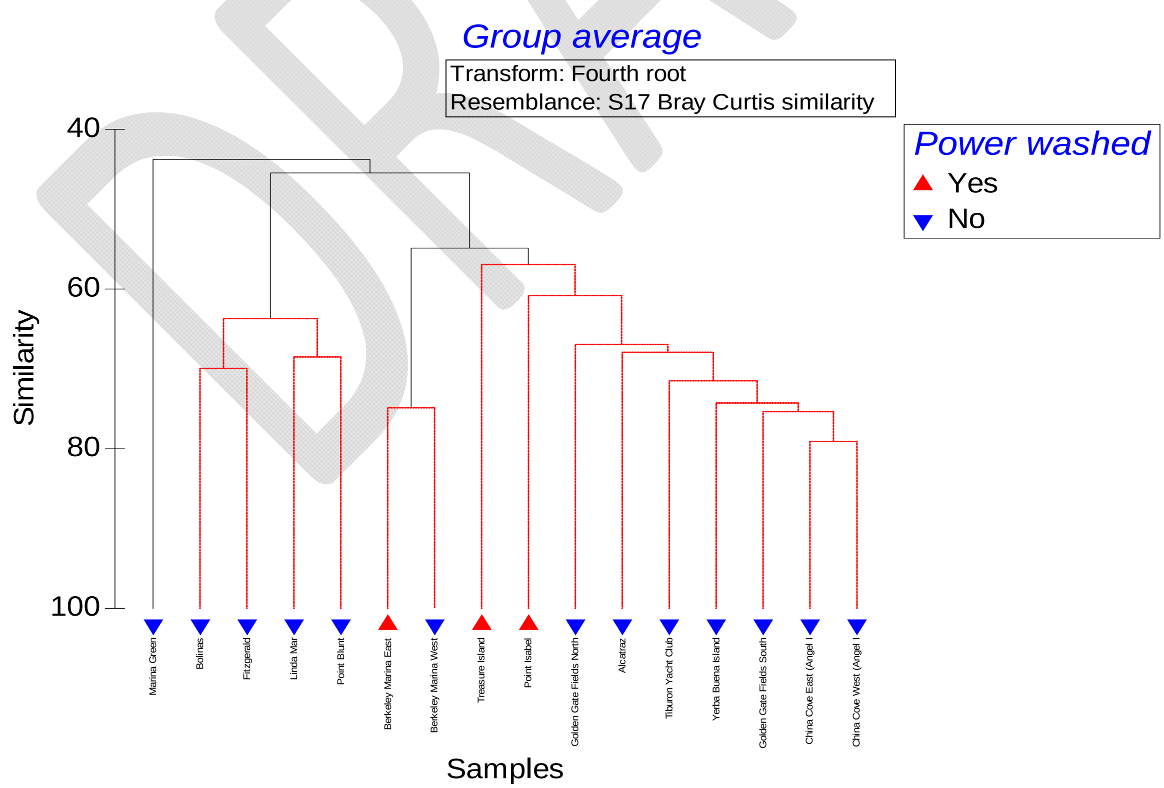


Figure 3: Cluster analysis for point intercept data: Symbols represent Power Washing status.

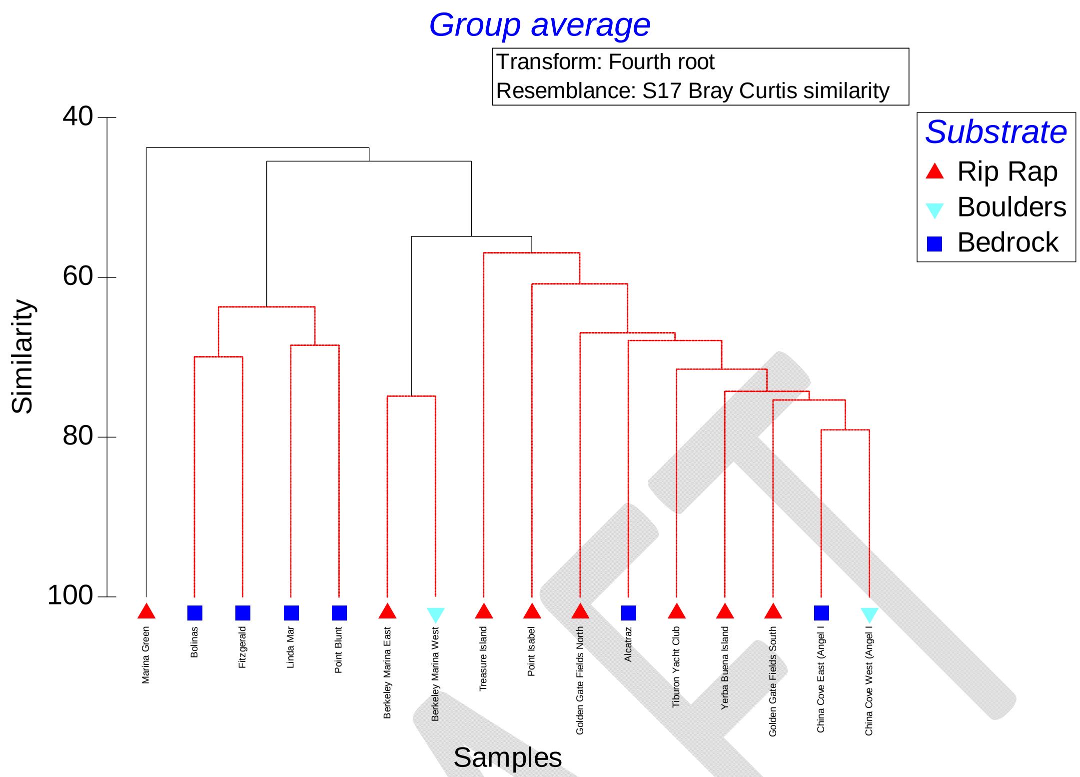


Figure 4: Cluster analysis for point intercept data: Symbols represent substrate type.

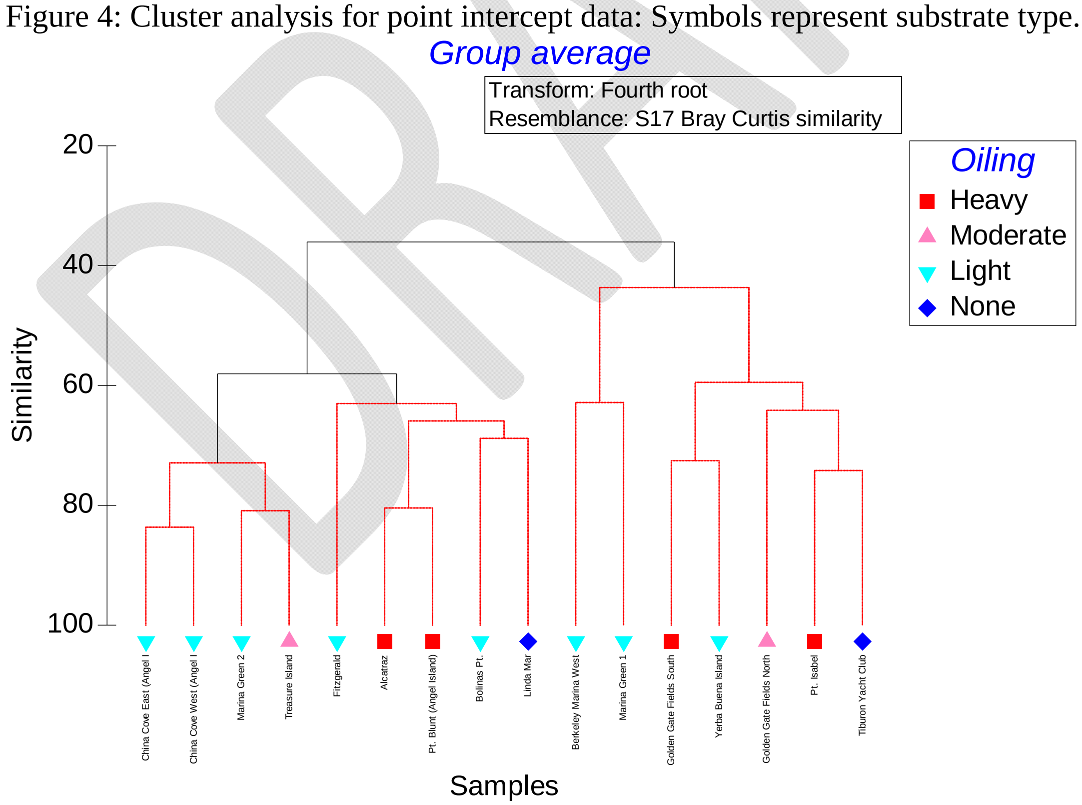


Figure 5: Cluster analysis for motile data: Symbols represent level of oiling (light and very light were combined for this figure).

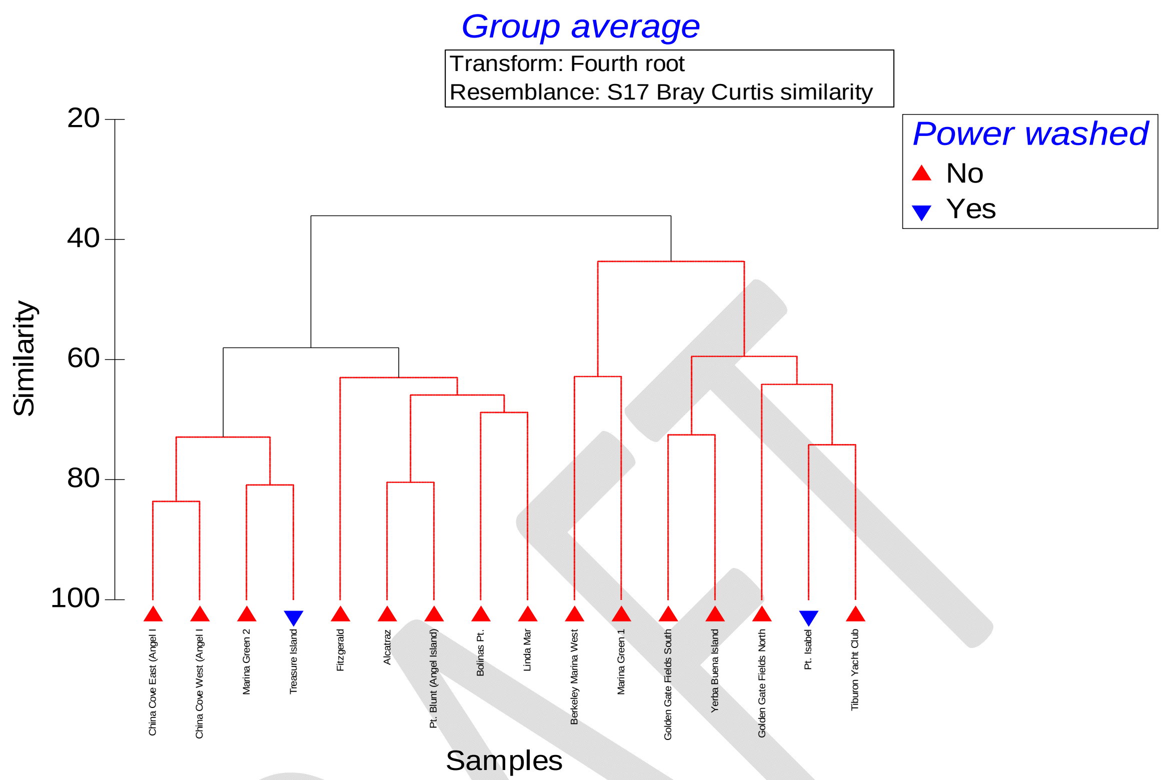


Figure 6: Cluster analysis for motile data: Symbols represent Power Washing status.

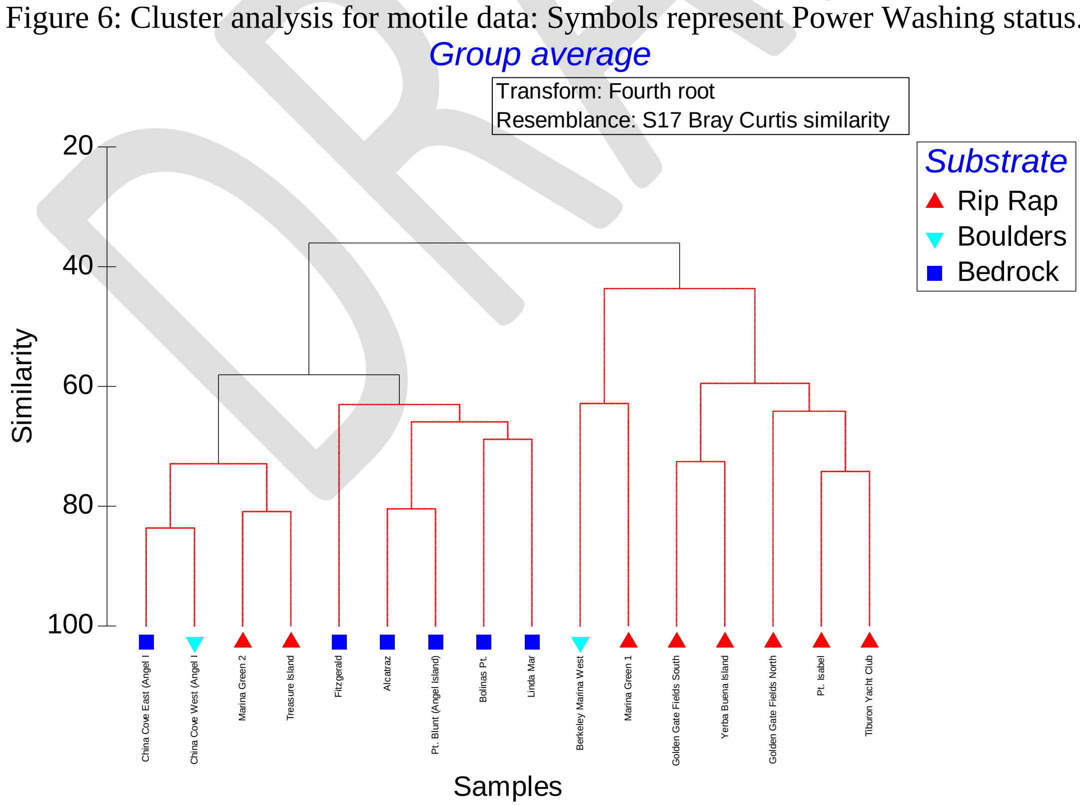


Figure 7: Cluster analysis for motile data: Symbols represent substrate type.

Assessment across locations – *Fucus* size Structure

We collected information on *Fucus* size structure at sites visited in January and February 2009. *Fucus* is sensitive to oiling and to power-washing (Houghton et al., 1996; Lees et al., 1996; Stekoll and Deysher 2000, Driskell et al. 2001), and its size structure was viewed as a potentially sensitive estimator of impacts. The results of the sampling are shown below in three figures: first (Figure 8) the dot-histograms of size frequency at all sites, second the mean size as a function of site (Figure 9) and third, an analysis of the size structuring using the same clustering analysis discussed above (Figure 10). Instead of species abundance serving as original variables in the analysis, size classes were used (25 mm bins). The sites most different with respect to size structure were Point Isabel and Point Blunt, which both had size distributions that were much shorter (length) than most other sites (note that at Point Isabel there were few individuals within the sample area = 23). These were also sites with heavy oiling and other anthropogenic impacts associated with the oiling (cutting of fronds and power-washing). It has been noted that the *Fucus* transect for the Point Blunt location was located in a geomorphically unstable area with sand and cobble crossing the transect. The dynamic nature of this sanded in habitat and its effect on algae has been noted at this location by Paul Silva (1974). However, as seen in photos 2-3, 2-4 and 2-5, at the time of the spill there was considerable *Fucus* cover at Point Blunt.

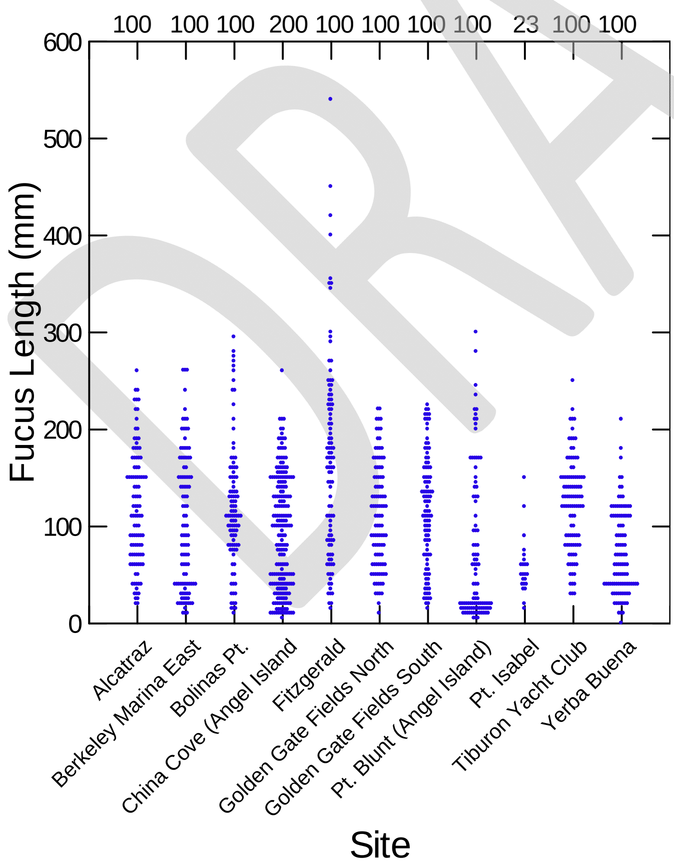


Figure 8: Fucus size structure (numbers at top of figure are sample sizes).

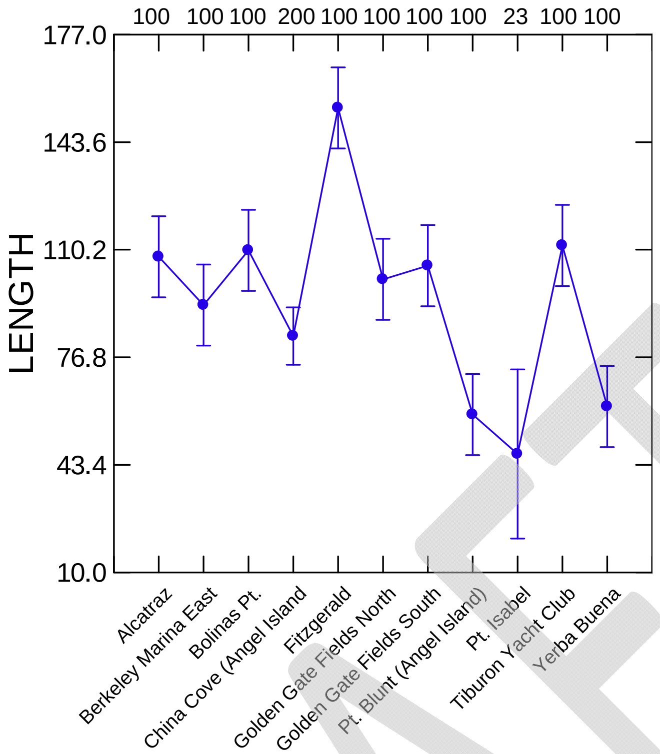


Figure 9: Mean length in mm (SE) of *Fucus* individuals at sample sites. Numbers at top of graph are sample sizes.

Fucus Length

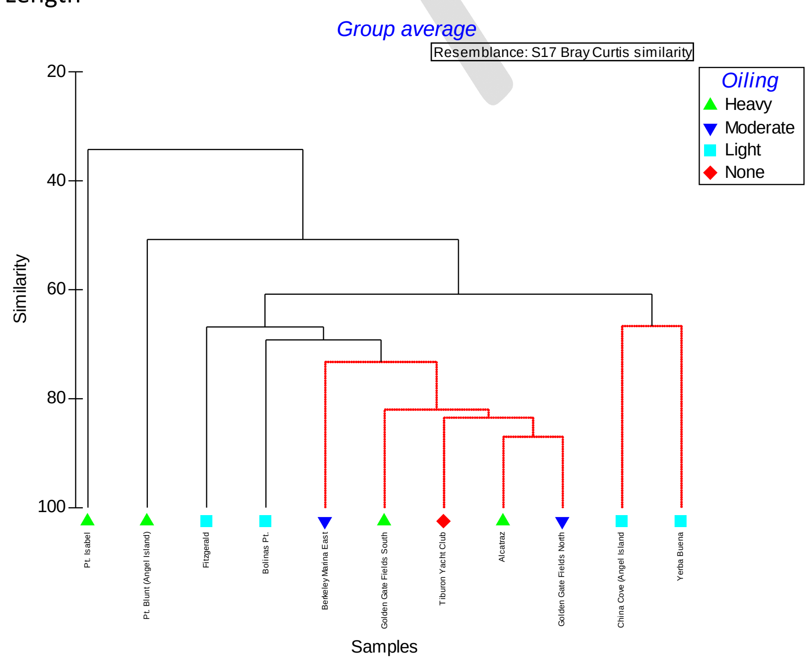


Figure 10: Cluster analysis of *Fucus* size structure by level of oiling (light and very light were combined for this figure).

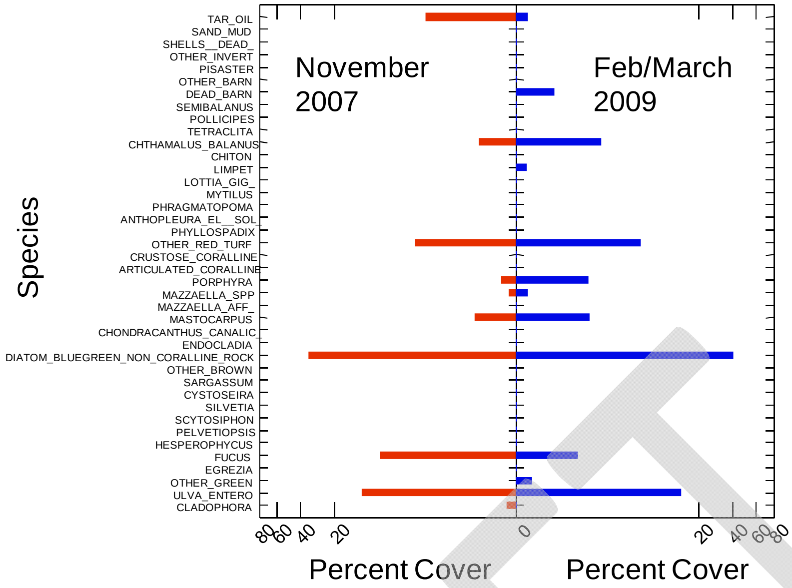
Assessment within locations (across time)
The other approach to address the potential direct and indirect impacts resulting from the oil spill is to assess species composition (species identity and abundances) relative to baseline information. There are a number of ways to estimate baseline conditions; these are discussed below. As noted above, establishing baseline information is difficult because of the near complete absence of pre-oil spill rocky intertidal information in the bay, where much of the rocky intertidal habitat oiling occurred.

Between just oiled period (November/December 2007) and post-oiled period (February/March 2009 – also see Figures 2-12 to 2-14 in Appendix 2)
Here we evaluated species composition at four sites based on photos taken during the spill period and another set taken in 2009. Here we only used pairs of photos that had the following characteristics: (1) the pairs were clearly in the same location, (2) species could be identified, (3) oil, if present, could be identified. Four sites were selected for evaluation.

1. Alcatraz (heavy oiling)
2. Point Isabel (heavy oiling and powerwashed)
3. Berkeley Marina (moderate oiling and powerwashed)
4. Marina Green (very light oiling)

Slides were scored and species composition was compared (during vs. post-oiling) using Bray-Curtis similarity scores followed by an ANOSIM procedure (analysis of similarities, PRIMER E). When significant, species abundances were compared. The following figures and photos show the results of the analyses and characteristic photos.

Analysis suggested that Alcatraz and Point Isabel had different species compositions in the two sampling periods. At Alcatraz the results clearly pointed to a pronounced impact that affected certain species. In particular *Fucus* (a long lived species with very limited dispersal) abundance dropped considerably between 2007 and 2009, as well as the cover of oil, while the cover of barnacles and *Porphyra* (both species that take advantage of open rock surfaces) increased dramatically. At Point Isabel the difference was driven in large part by the decrease in oil cover between 2007 (during the spill) and 2009. There was no change in species composition at Berkeley Marina ($p=0.60$) between 2007 and 2009. Due to access restrictions, sampling did not occur until after power-washing so the species composition that was present pre-oiling was not assessed. In both periods the area was dominated by bare rock, diatoms, sand or mud and ephemeral green algae. The species composition at Marina Green, which was lightly oiled (we saw no oil at our sampling site) was not expected to change and it did not ($p=0.84$).



P=0.003

Figure 11: Percent cover of taxa and substrate at Alcatraz in 2007 and 2009.

2007

2009

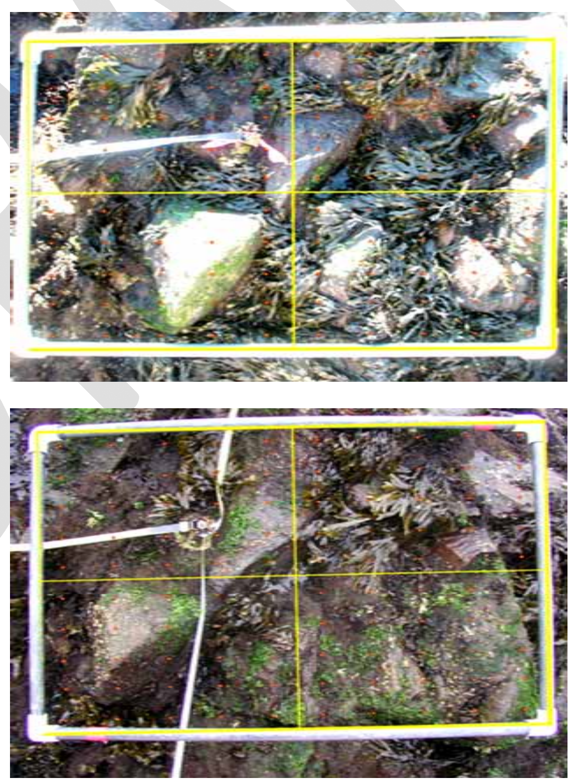


Figure 12: Representative photoplot at Alcatraz in 2007 and in 2009. Dark bladed algal species is *Fucus*.

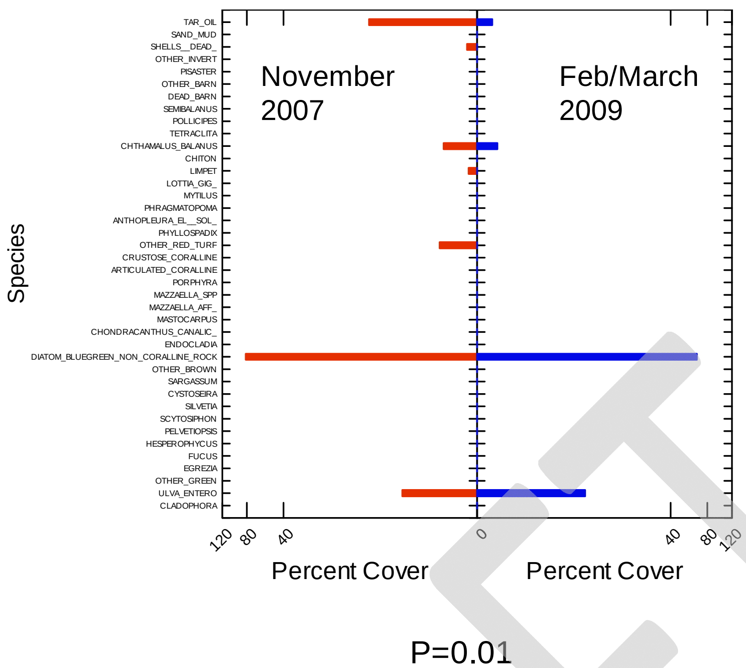


Figure 13: Percent cover of taxa and substrate at Point Isabel in 2007 and 2009.

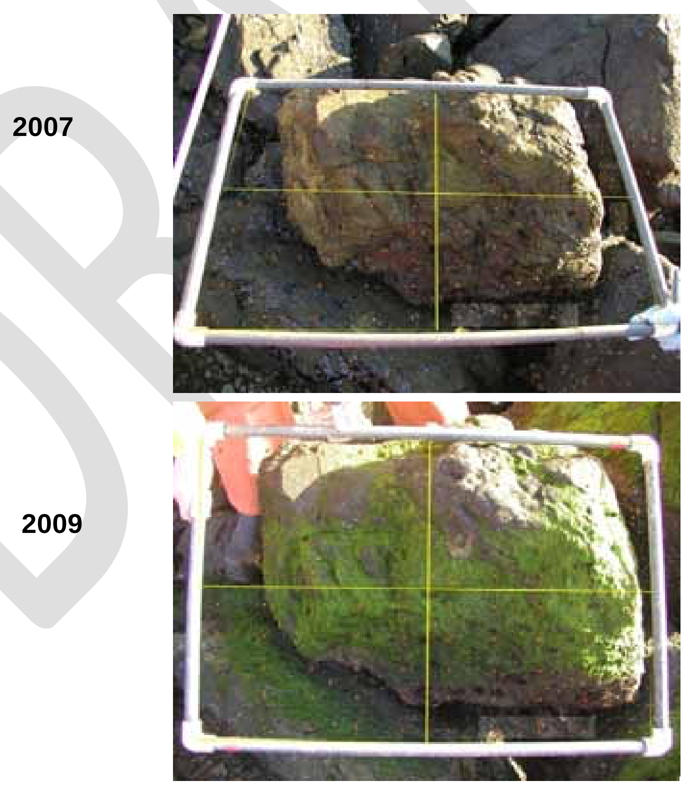


Figure 14: Representative photoplot at Point Isabel in 2007 and in 2009.

Between pre and post spill periods at Alcatraz
Because data have been collected at our Alcatraz site for a number of years we were able to use this information to more rigorously investigate whether an impact occurred at Alcatraz in 2007. We took two approaches to address this question.

Biodiversity samples 2005, 2009
PISCO (Partnership for Interdisciplinary Study of Coastal Oceans) biodiversity sampling (http://cbsurveys.ucsc.edu/) was carried out at Alcatraz in 2005 and 2009 (methods described above) and this allowed a comparison of the species composition from a period pre-spill to a period 15 months post-spill. In order to give a context to this comparison we also compared species compositions for sites that had been sampled twice within the period 2000-2009. All reference sites were from coastal areas within the same biogeographic region that contains Alcatraz. For each reference site we calculated the Bray-Curtis similarity between times. This set of similarities was statistically resampled yielding a distribution of expected pairwise (over time) similarities under the assumption of underlying natural variability (Note that any additional variability driven by anthropogenic causes would yield lower similarity values). The similarity value for Alcatraz (2005, 2009) was then compared to the expected range of similarities, yielding a p-value = 0.001 (Figure 15). This means that the species composition at Alcatraz was more different between the periods sampled than would be expected due to natural variability. The changes in species are revealing (Figure 16). *Fucus*, *Mytilus californianus* (mussels) and all other long-lived species were more abundant in 2005 than in 2009, while rock and opportunistic or ephemeral species were more abundant in 2009.

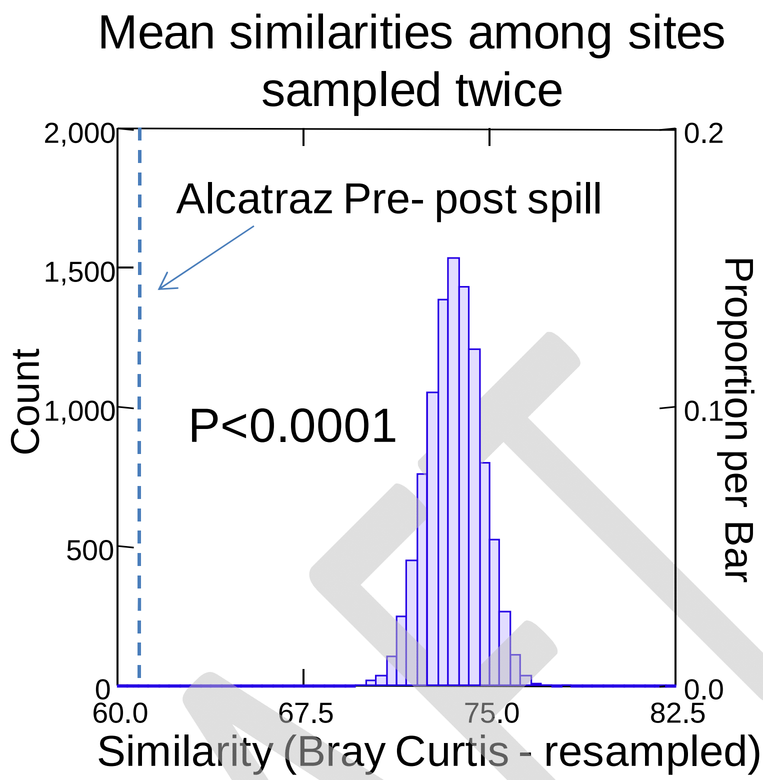


Figure 15: Similarity at Alcatraz pre and post-spill compared to that expected from reference sites sampled twice.

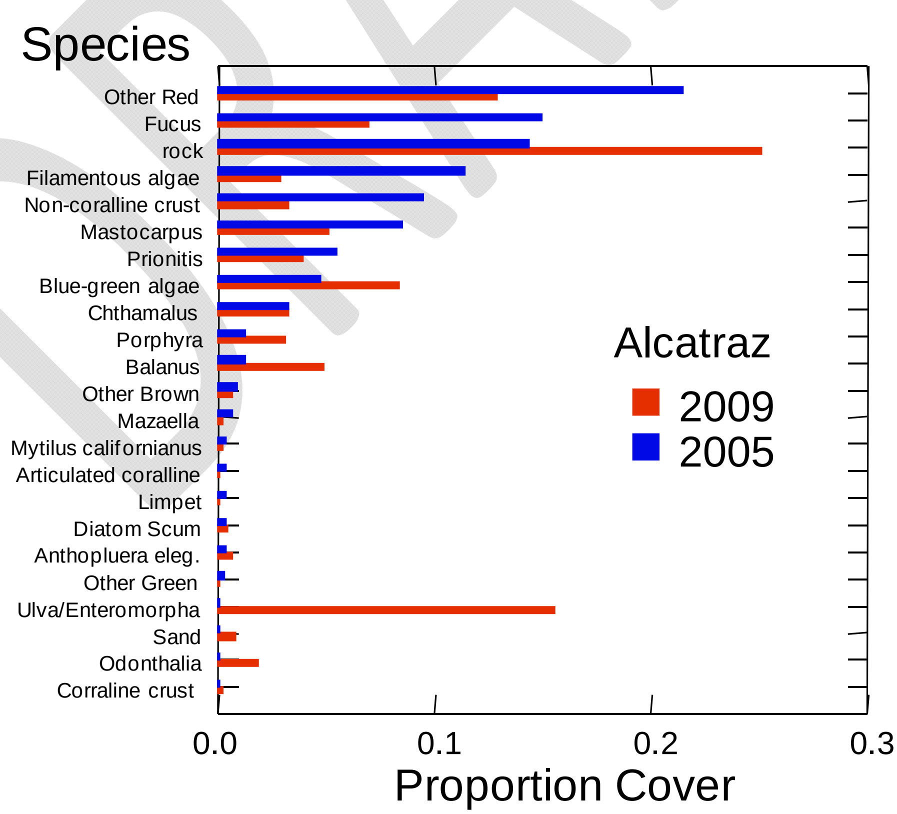


Figure 16: Change in species composition pre vs. post-spill at Alcatraz.

Park Service (MARINe) photoplots (2006, 2007, 2008)
In addition to the biodiversity sampling done at Alcatraz, the Park Service has been using MARINe protocols to sample photoplots (permanent) at Alcatraz. Photos were taken in a variety of species assemblages in November of 2006 (pre-spill), 2007 (during spill) and 2008 (post-spill). As before the analysis makes use of Bray-Curtis similarities followed by an ANOSIM (analysis of similarities) procedure. Here the null prediction is very simple. All sites will show a level of natural variation, and if there is no anthropogenic impact then there should be little pattern in the species composition across years. If there was an anthropogenic impact in 2007, then demonstrated differences across years will be in addition to natural variation and the changes seen, (both in terms of species affected and type of change), which should be consistent with the types of impacts potentially associated with oil spills. The results of this analysis are shown below in the form of a Multidimensional Scaling plot (note the ANOSIM tests for years below, Figure 17). The results indicate an anthropogenic impact occurred in 2007, as the years differ significantly from each other. On the Multidimensional Scaling (MDS) plot each symbol represents a photoplot and the spatial arrangement of the symbols indicates similarity in species composition among the photoplots. In Figure 18, species abundances are shown as a function of year. The changes in species abundances are consistent with an impact in 2007. Oil (tar sheen) was high in 2007 but not in 2006 or 2008, *Fucus* dropped dramatically between 2007 and 2008, while the ephemeral species *Ulva* and *Porphyra* increased between 2007 and 2008. Barnacles and Rock cover decreased in 2007 then increased in 2008 (the reverse pattern from tar sheen).

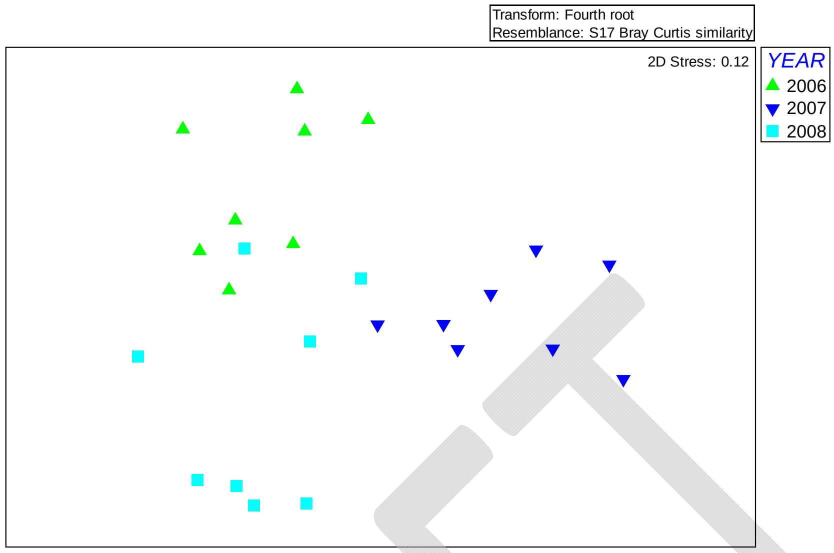
It is important to test the idea that that these effects were due to some sort of natural change in the community unrelated to an impact. We compared the species abundances over the 3 year period to five reference sites outside the influence of the spill using taxa or substrate variables that we felt were comparable between the sampling done for PISCO (reference sites) and that done at Alcatraz by the Park Service. These included: *Fucus*, *Mastocarpus*, barnacles, *Porphyra*, rock and oil/tar (the tar category excludes points where tar was on an organism – hence is probably an under-estimate of the cover of tar). The predictions for each group with respect to the impact of oiling varied and are listed below. Note that the oil spill occurred just before the 2007 sampling. All predictions are for Alcatraz relative to reference sites

1) *Fucus* should decrease between 2007 and 2008. Sampling in 2007 was just after the oiling (within a month) at Alcatraz and the effects on cover would not have been apparent at that point. The expectation is that oiling would have caused loss of cover over time.
2) *Mastocarpus* would decrease between 2006 and 2007 then start to recover. Oil sticks to *Mastocarpus* and the effects on this species would be more immediate than *Fucus*.
3) *Porphyra* should increase between 2007 and 2008 as it is an opportunistic species that occupies areas that have been recently disturbed.
4) Tar-Sheen (oiling) should increase between 2006 and 2007 then decrease between 2007 and 2008.
5) Barnacles should decrease between 2006 and 2007 as they are covered in oil then increase to higher levels in 2008 with recruitment to newly opened areas (from disturbance).

6) Rock should decrease from 2006-2007 (as it is covered up by oil), then recover between 2007 and 2008 (partly in response to wearing away of the oil).

Only plots that were sampled in all years (3 years 2006-2008) were used. Because the Park Service photoplots were for a variety of assemblages in the mid to high intertidal we used PISCO photoplots for the same tidal height (*Fucus* and Barnacles). All such plots were used in analyses. Site to site differences were large hence we transformed all data to standard deviates by adjusting each value to the mean and standard deviation for that species at each site. Mean values were generated for each group for site by year combinations because sites (not plots) are the unit of replication. A new dataset was created by subtracting each value from its starting condition in 2006. As an example, the value for *Fucus* at Alcatraz in 2007 was subtracted from the value for *Fucus* at Alcatraz in 2006, yielding the change from starting condition. This allowed direct exploration of the change in communities from pre-spill condition. Figure 19 is a cluster analysis looking at site by year combinations of such values. 2006 is not shown as by definition there was no change in that year (all values = 0). Importantly, only two site-year combinations cluster separately: Alcatraz in 2007 and Alcatraz in 2008. This means that the change in community at Alcatraz since the oil spill is unlike any other reference site. **No other site showed a difference between years, which suggests that the cause of the difference at Alcatraz between years was not due to broader regional changes.** Note also the scale of clustering, which shows how different post-spill Alcatraz was.

Figure 20 provides explanation for this difference. Each examined group shows marked differences at Alcatraz relative to reference sites and the pattern of the effects over time are consistent with the prediction discussed above. [Note: It is likely that individual reference sites might also show differences from other sites for one or more species or substrate group. However, based on the results of the cluster analysis such differences did not lead to distinct clustering, which was seen for Alcatraz in 2007 and 2008].



Pairwise Tests

Groups	R Statistic	Significance Level	Possible Permutations	Actual Permutations	Number >= Observed
2006, 2007	0.88	0.001	6435	999	0
2006, 2008	0.528	0.001	6435	999	0
2007, 2008	0.747	0.001	6435	999	0

Figure 17: MDS plot and ANOSIM results for comparison of community composition at Alcatraz over the period 2006-2008.

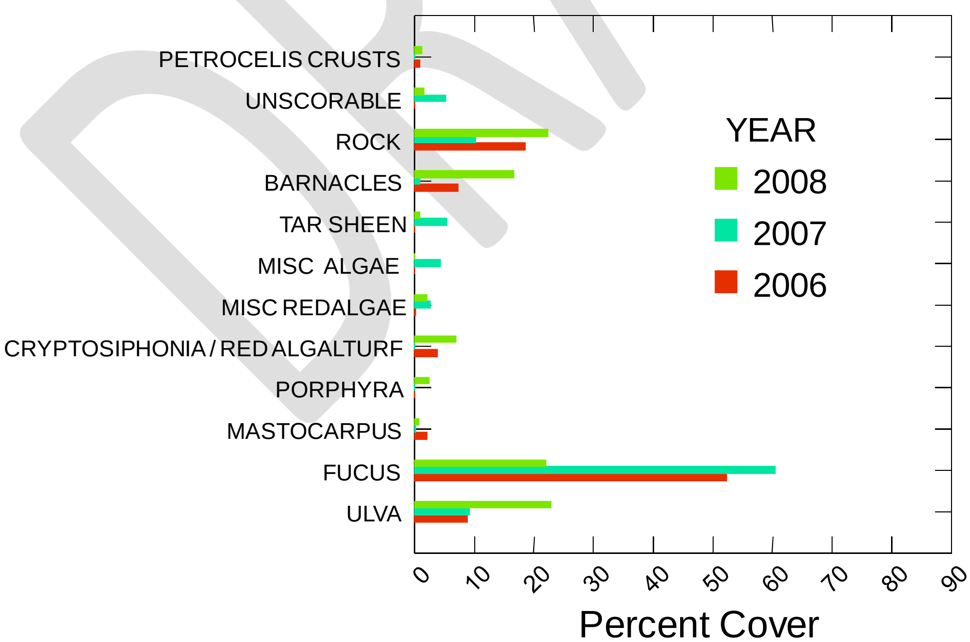


Figure 18: Community composition at Alcatraz over the period 2006-2008.

Trends at Alcatraz compared to five reference sites

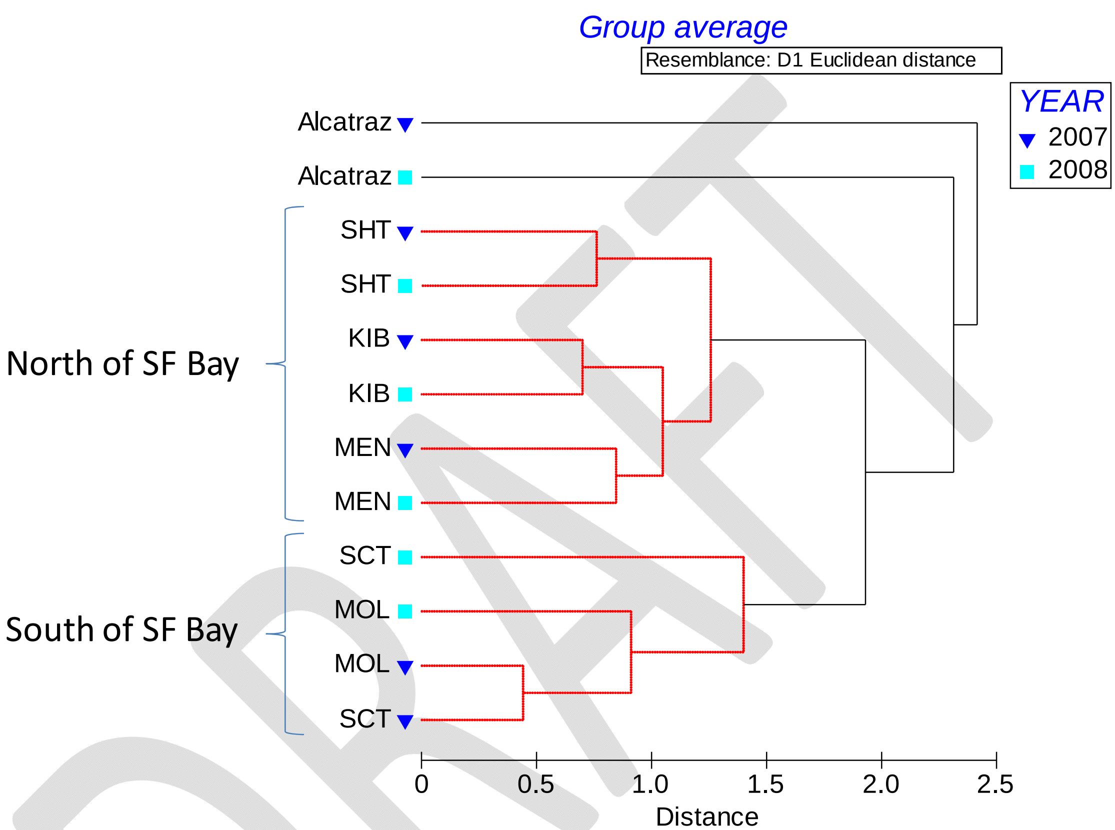


Figure 19: Comparison of Alcatraz to other sites over the three year period of 2006-2008. Clusters of sites or individual sites that are separated by black lines are significantly different at P<0.05. Note that there are 4 distinct clusters: Alcatraz in 2007, Alcatraz in 2008, a cluster of sites to the north of San Francisco Bay in both years, a cluster of sites to the south of San Francisco Bay in both years.

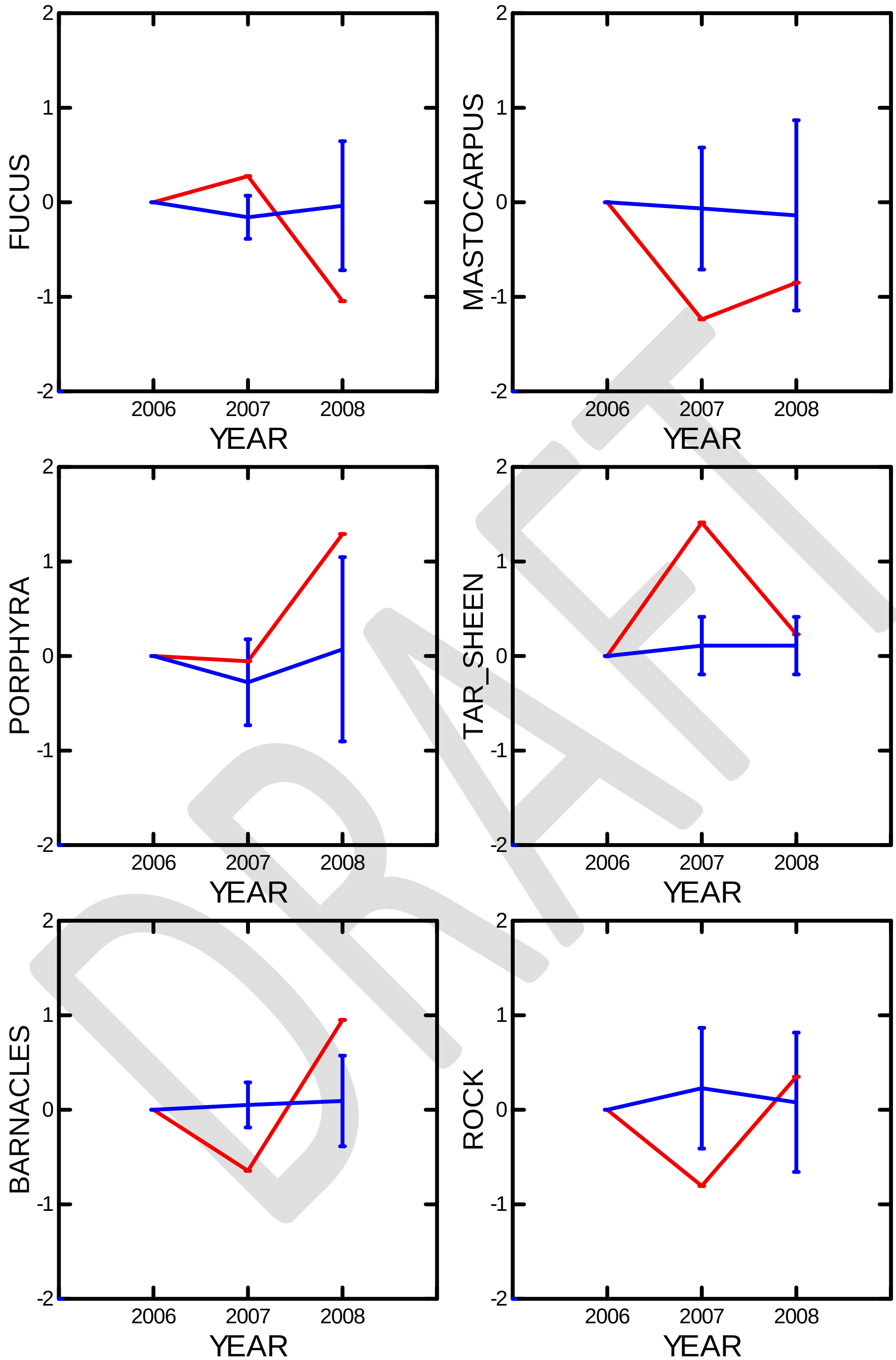


Figure 20: comparison of six groups at Alcatraz (red lines) to expected values from reference sites (blue lines). Data plotted are standard deviates (mean =0, sd =1) relative to 2006. Hence the patterns reflect change (in terms of standard deviates) relative to 2006. Error bars are 95% confidence intervals.

Appendix 1: Site Characteristics

Outer Coast Sites

Alcatraz


Photo taken on 01-23-2009

The sampled area at Alcatraz (SCAT segment SFH001) is located at 37.82513˚N, -122.42207˚W and is a small bedrock bench. This is a long term monitoring site with restricted access. Alcatraz is an island located near the mouth of the San Francisco Bay. It is only accessible by boat and is controlled by the National Parks Service. While tourists are allowed on the island the area sampled is off limits to the public. The area was heavily oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site was visited just after the spill on 12-07-2007, and crab and seastar searches as well as photo sampling were completed. *F. gardneri* was found to be present at that time but there were no data on its condition. The CBS Team sampled the site on 12-07-2007 after the spill. The site was also revisited on 1-23-2009 for additional sampling. *F. gardneri* sampling, point contacts, motile invertebrate counts, timed shore crab and seastar counts, GPS tracking, mussel collection and photo sampling took place on 1-23-2009. The tide was -0.3ft at 16:29 and sampling was conducted from before to just after the low tide. There were strong currents associated with the dropping tide but no swell. It was raining upon arrival but stopped shortly after. The wind was calm.

Bolinas


Photo taken on 02-08-2009

The Bolinas (SCAT segment MRL002C) site is located at 37.90430˚N, -122.72713˚W and is a very large bedrock bench. This is a long term monitoring site. Access to the site is difficult; it is surrounded by coastal bluffs and pastures. This area was very lightly to lightly oiled during the Cosco Busan oil spill according to SCAT data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. Bolinas was sampled by the CBS team on 02-16-2008 after the spill. *F. gardneri* was found to be present at that time but there are no data on its condition. This site was also visited on 02-08-2009 for additional sampling. *F. gardneri* sampling, point contacts, motile invertebrate counts, timed shore crab and seastar counts, GPS tracking, mussel collection and photo sampling took place on 02-08-2009. The tide was -1.4ft at 16:13 and sampling was conducted from before to just after the low tide. There was small swell and moderate wind with rain.

Fitzgerald


Photo taken on 02-10-2009

The Fitzgerald (SCAT segment SML005A) site is located at 37.51694˚N, - 122.51325˚W and is a large bedrock bench. The site is surrounded by coastal bluffs and cliffs with houses on them. A park with public beach access is located approximately 880 m from the site and a parking lot on the cliff (approximately 220 m from the site) appears to have a trail from it down the cliff. There is also a beach cottage near the site. This site was very lightly oiled during the Cosco Busan oil spill according to SCAT data.

Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site was visited during the initial surveys following the oil spill on 12-08-2007. *F. gardneri* was found to be present and in typical condition at that time. Photo sampling and shore crab and seastar searches were conducted at that time. This site was revisited on 02-10-2009, there was a -0.6ft low tide at 17:09. Sampling was conducted from before low tide to just after low tide. There was small swell, low wind and no rain. *F. gardneri* sampling, point contacts, motile invertebrate counts, timed shore crab and seastar counts, GPS tracking, mussel collection and photo sampling took place at this time.

Linda Mar

Photo taken on 02-09-2009

The Linda Mar (SCAT segment SMK005) site is located at 37.60424˚N, -122.49983˚W and is a small bedrock/boulder bench. This site is located next to a public beach alongside and within plain view of Highway 1. There was no observed oil here during the Cosco Busan oil spill according to SCAT data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site was visited during the original bio surveys following the oil spill on 11-11-2007. *F. gardneri* was not present at that time. Photo sampling and shore crab and seastar searches were conducted at that time. This site was revisited on 02-09-2009, there was a -1.0ft low tide at 16:30. Sampling was conducted from before low tide to just after low tide. There was small swell, high wind and no rain. Point contacts, motile invertebrate counts, timed shore crab and seastar counts, GPS tracking, mussel collection and photo sampling took place at this time. No *F. gardneri* or any other rockweed was present at the site. The site appeared to be heavily sand influenced (based on its proximity to a large beach and the algal assemblage present at the site).

Inner Bay Sites

Golden Gate Fields South


Section A Section B Photos taken on 02-25-2009

The Golden Gate Fields South (SCAT segment ALA005) consisted of two small riprap jetties and was split into two sections. Section A is located at 37.88577˚N, -122.31644˚W on the northern side of the southern jetty. Section B is located at 37.88611˚N, -122.31619˚W on the northern side of the northern jetty. Both sections were on northern sides of the jetties because we were targeting the heavily oiled area of the segment. This site is directly adjacent to the parking lot for Golden Gate Fields race track. It is near a dog beach and it is easily accessible to the public. The area sampled was heavily oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. These sections were sampled on 02-25-2009, when there was a 0.3ft low tide at 18:13. There was low swell, overcast skies with light rain and moderate wind. Sampling was conducted on both sections starting before low tide until low tide. *F. gardneri* sampling, point contacts, motile invertebrate counts, timed shore crab counts, GPS tracking and photo sampling were conducted at both sections. Mussels were collected only from section B of the site at that time. Because there did not appear to be seastars or appropriate habitat for seastars at the site a search was not conducted.

Point Blunt

Photo taken on 02-05-2009

Point Blunt (SCAT segment MRR001) is located at 37.85285˚N, -122.41870˚W and is a boulder / bedrock site resembling substrate more commonly found on the outer coast. This site was heavily oiled during the Cosco Busan oil spill according to SCAT survey data. No power washing took place here but *F. gardneri* removal took place at the site and the amount removed is unknown. This site is on a Coast Guard controlled side of Angel Island and is only accessible by boat. It is on the southeast portion of the Island. There is no public access to the site. This site was sampled on 02-05-2009, when there was a -0.6ft low tide at 14:35. There was low swell, moderate wind with cloudy skies and rain all around the island but not on it. Although it did not rain on the site at that time, it was apparent that it had earlier that day. Sampling was conducted starting before low tide until shortly after low tide. *F. gardneri* sampling, point contacts, motile invertebrate counts, timed shore crab counts, GPS tracking, photo sampling and mussel collection were conducted on this date. There appears to be some sand influence at the site based on the presence of channels with sand in them.

Point Isabel

Photo taken on 01-27-2009

The Point Isabel (SCAT segment CCZ025) site is located at 37.89748˚N, -122.32448˚W and is a site containing riprap, boulders and cobble. This site was heavily oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing took place at this site. It is not known whether or not *F. gardneri* removal took place at this site. This site is located next to a dog park and is easily accessible by the public. This site was previously photo sampled on 11-21-2007 during the original bio survey after the oil spill. *F. gardneri* was found to be present but damaged at that time. This site was revisited and sampled on 01-27-2009, when there was a -0.2ft low tide at 18:49. There was low swell, moderate wind with clear skies. Sampling was conducted starting before low tide and concluded just before low tide. *F. gardneri* sampling, point contacts, motile invertebrate counts, timed shore crab and seastar counts (although there was not suitable habitat for seastars), GPS tracking, photo sampling and mussel collection were conducted on this date.

Berkeley Marina East


Photo taken on 01-24-2009

The Berkeley Marina East (SCAT segment ALA011C) site is located at 37.86267˚N, -122.31458˚W and is primarily composed of riprap. This site was moderately oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing took place at this site. It is not known whether or not *F. gardneri* removal took place at this site. This site is located next to a park directly adjacent to Berkeley Marina West (SCAT segment ALA011C) and is easily accessible by the public. This site was sampled on 01-24-2009, when there was a -0.4ft low tide at 17:22. There was low swell and wind with partly cloudy skies. Sampling was conducted starting before low tide until just after low tide. *F. gardneri* sampling, point contacts, timed shore crab and seastar counts (although there was not suitable habitat for seastars), GPS tracking, mussel collection were conducted on this date.

Berkeley Marina West


Photo taken on 01-24-2009

The Berkeley Marina West (SCAT segment ALA011C) site is located at 37.86168˚N, -122.31577˚W and is primarily composed of boulders. This site was lightly oiled according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site is located next to a park directly adjacent to Berkeley Marina East (SCAT segment ALA011C) and is easily accessible by the public. This site was photo sampled on 10-12-2007 and *F. gardneri* was found to be present but damaged at that time. This site was sampled again on 01-24-

2009, when there was a -0.4ft low tide at 17:22. There was low swell and wind with partly cloudy skies. Sampling was conducted starting before low tide until just after low tide. There was *F. gardneri* but it was sparse and appeared to be mostly recruits, so it was only sampled at Berkeley Marina East which had actual beds of *F. gardneri*. Point contacts, timed shore crab and seastar counts (although there was not suitable habitat for seastars), GPS tracking, and photo sampling were conducted on this date.

Golden Gate Fields North


Photo taken on 02-24-2009

The Golden Gate Fields North (SCAT segment ALA003) site is located at 37.88933˚N, -122.31825˚W and is composed of riprap. This site was moderately oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site is located next to a park directly adjacent to Golden Gate Fields race track and is easily accessible by the public. This site was sampled on 02-24-2009, when there was a 0.1ft low tide at 17:47. There was low swell and wind with clear skies. Sampling was conducted starting before low tide until just before low tide. *F. gardneri* sampling, point contacts, timed shore crab and seastar counts (although there was not suitable habitat for seastars), GPS tracking, photo sampling, and mussel collection were conducted on this date.

Treasure Island


Photo taken on 02-21-2009

The Treasure Island site (SCAT segment SFF004) is located at 37.82071˚N, -122.37511˚W and is composed of very steep riprap. This site was moderately oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did take place at this site. It is not known if *F. gardneri* removal took place at this site. This site is located on the west side of the island next to a park directly adjacent to the old Navy barracks and is easily accessible by the public. This site was sampled on 02-21-2009, when there was a 0.0ft low tide at 16:14. There was low swell (although it is hit by vessel wakes) and wind with overcast skies. Sampling was conducted starting before low tide until just before low tide. There was not any *F. gardneri* or other rockweeds at the site. Point contacts, timed shore crab and seastar counts, GPS tracking, photo sampling, and mussel collection were conducted on this date.

China Cove East


Photo taken on 02-06-2009

The China Cove East site (SCAT segment MRR008C) is located at 37.87052˚N, -122.42561˚W and is composed of a somewhat steep and narrow bedrock bench. This site was lightly oiled according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site is accessible only by boat and is part of the state park on Angel Island. It is located on the northeastern part of the island across the beach from China Cove West (SCAT segment MRR008A) and directly adjacent to the old Immigration Building. This area is now open to the public but was not at the time it was sampled. This site was photo sampled and searched for crabs and seastars during the original bio-survey work on 12-09-2007 following the oil spill. *F. gardneri* was present at that time but there is no data on its condition. This site was revisited and sampled on 02-06-2009, when there was a -0.9ft low tide at 15:29. There was low swell (although it is hit by vessel wakes) and wind with cloudy skies. It had rained earlier in the day. Sampling was conducted starting before low tide until just before low tide. *F. gardneri* sampling, point contacts, timed shore crab and seastar counts (although there was not suitable habitat for seastars), GPS tracking, and photo sampling were conducted on this date.

China Cove West


Photo taken on 02-06-2009

The China Cove West site (SCAT segment MRR008A) is located at 37.87061˚N, -122.42737˚W and is composed of a narrow boulder field. This site was lightly oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site is accessible only by boat and is part of the state park on Angel Island. It is located on the northeastern part of the island across the beach from China Cove East (SCAT segment MRR008C) and directly adjacent to the old Immigration Building. This area is now open to the public but was not at the time it was sampled. This site was photo sampled and searched for crabs and seastars during the original bio-survey work on 12-09-2007 following the oil spill. *F. gardneri* was present at that time but there was no data on its condition. This site was revisited and sampled on 02-06-2009, when there was a -0.9ft low tide at 15:29. There was low swell (although it is hit by vessel wakes) and wind with cloudy skies. It had rained earlier in the day. Sampling was conducted starting before low tide until just before low tide. *F. gardneri* sampling, point contacts, timed shore crab and seastar counts (although there was not suitable habitat for seastars), GPS tracking, and photo sampling were conducted on this date.

Marina Green


SFH10 Photo taken on 01-26-2009


SFH11 Photo taken on 01-26-2009

The Marina Green site is split into two sections, SCAT segment SFF010 and SFF011. SFF010 is located at 37.80494˚N, -122.46223˚W and has some riprap but is mostly sand. This segment is located on the beach near the Gulf of the Farallones and is easily accessible to the public. This site was very lightly oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site was photo sampled and searched for crabs and seastars during the original bio-survey work on 11-21-2007 following the oil spill. *F. gardneri* was not present at that time. This site was revisited and sampled on 01-26-2009, when there was a -0.3ft low tide at 17:43. There was low swell (although it is hit by vessel wakes) and wind with clear skies. Sampling was conducted shortly before low tide. There was not any *F. gardneri* or other rockweeds at this section nor was there proper habitat for fucoid species. Point contacts, timed shore crab and seastar counts (although there was not suitable habitat for seastars), GPS tracking, and photo sampling were conducted on this date at this segment.

Section SFF011 is located at 37.80805˚N, -122.44208˚W and is a steep riprap site. This segment is located near the mouth of the marina and next to the Yacht Club and is easily accessible to the public. This site was very lightly oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site was photo sampled and searched for crabs and seastars during the original bio-survey work on 11-21-2007 following the oil spill. *F. gardneri* was not present at that time. This site was revisited and sampled on 01-26-2009, when there was a -0.3ft low tide at 17:43. There was low swell (although it is hit by vessel wakes) and wind with clear skies. Sampling was conducted before low tide and concluded just before the low tide. There was no *F. gardneri* or other rockweed at this section. Point contacts, timed shore crab and seastar counts, GPS tracking, and photo sampling were conducted on this date at this segment.

Yerba Buena Island


Photo taken on 02-25-2009

The Yerba Buena Island site (SCAT segment SFF007) is located at 37.81158˚N, -122.36109˚W and is composed of riprap. This site was lightly oiled during the Cosco Busan oil spill according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site is located on the eastern part of Yerba Buena Island and is on a Coast Guard base with restricted access. The area sampled was directly adjacent to the Coast Guard docks. Arrangements must be made with the Coast Guard to access the site. This site was sampled on 02-25-2009, when there was a 0.3ft low tide at 18:10. There was low swell and wind with overcast skies. Sampling was conducted starting before low tide and was concluded before low tide. *F. gardneri* sampling, point contacts, timed shore crab and seastar counts, GPS tracking, and photo sampling were conducted on this date.

Tiburon Yacht Club


Photo taken on 02-20-2009

The Tiburon Yacht Club site (SCAT segment MRS005) is located at 37.91674˚N, -122.47495˚W and is composed of steep riprap. There was no observed oil at this site according to SCAT survey data. Power washing did not take place at this site and it is unknown if *F. gardneri* removal took place here. This site is located on the east side of Tiburon Point near the mouth of the marina and next to the Yacht Club. This site is easily accessible to the public. This site was sampled on 02-20-2009, when there was a 0.2ft low tide at 15:26. There was low swell (although it is hit by vessel wakes) and wind with clear skies. Sampling was conducted starting before low tide and was concluded shortly before low tide. *F. gardneri* sampling, point contacts, timed shore crab and seastar counts, GPS tracking, and photo sampling were conducted on this date.

Satellite Overviews of Sites

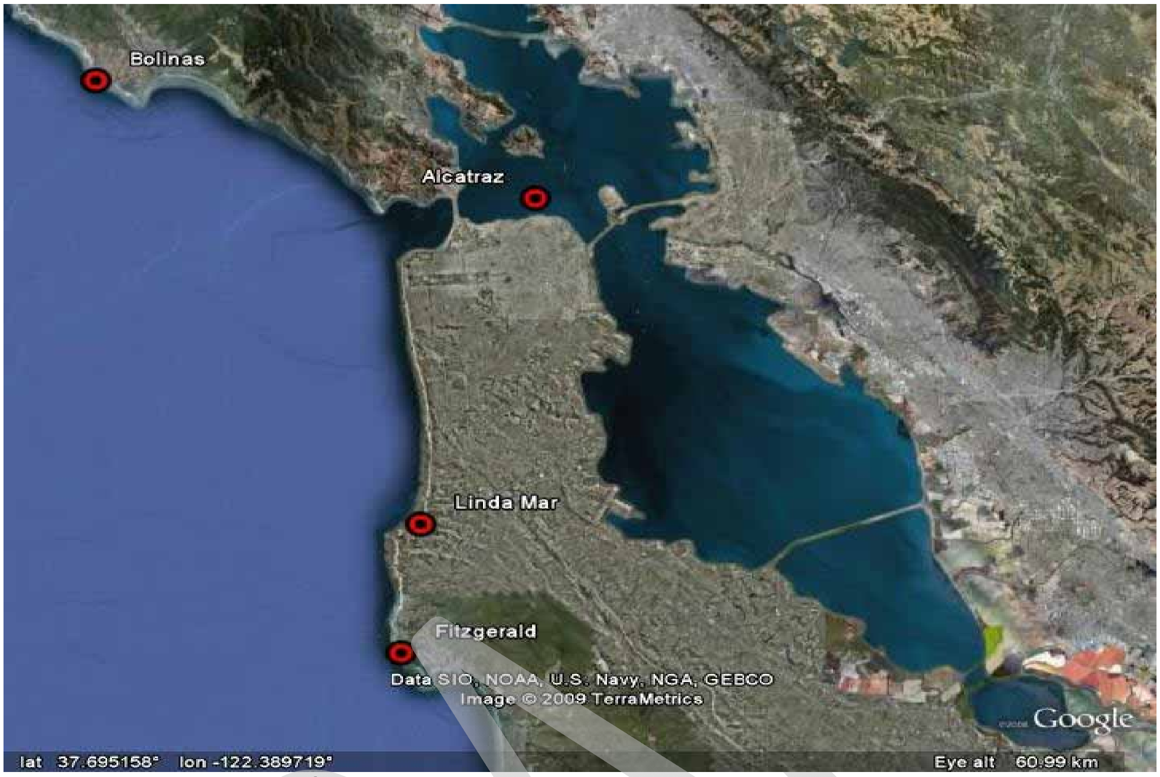


Figure 1-1: Satellite overview of outer coast sites

Figure 1-2: Satellite overview of in-Bay sites

Figure 1-3: The site of sampling at Alcatraz showing level of oiling per Shoreline Cleanup and Assessment Team Surveys (GIS data revised 09 Feb. 2009).

Figure 1-4: The site of sampling at Bolinas showing the level of oiling.

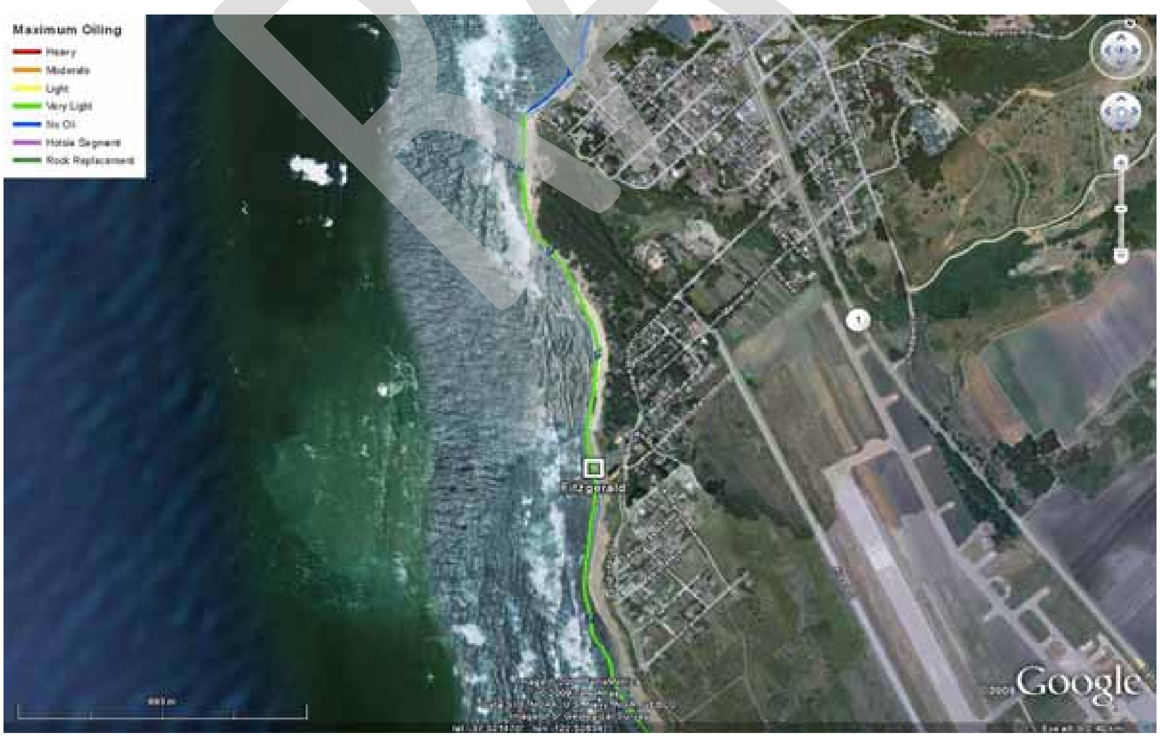


Figure 1-5: The site of sampling at Fitzgerald showing the level of oiling.

Figure 1-6: The site of sampling at Linda Mar showing the level of oiling.

Figure 1-7: The site of sampling at Berkeley Marina East and West showing the level of oiling and the Hotsie segment. Hotsie segment refers to the area power washed.

Figure 1-8: The site of sampling at China Cove East and West showing the level of oiling.

Figure 1-9: The site sampled at Golden Gate Fields North showing the level of oiling.

Figure 1-10: The sites sampled at Golden Gate Fields South showing the level of oiling.

Figure 1-11: The site sampled at Marina Green SFH10 showing the level of oiling.

Figure 1-12: The site sampled at Marina Green SFH11 showing the level of oiling.

Figure 1-13: The site sampled at Point Blunt showing the level of oiling.

Figure 1-14: The site sampled at Point Isabel showing the level of oiling and the Hotsie segment. The Hotsie segment is the area were power washing took place.

Figure 1-15: The site sampled at Tiburon Yacht Club showing the level of oiling.

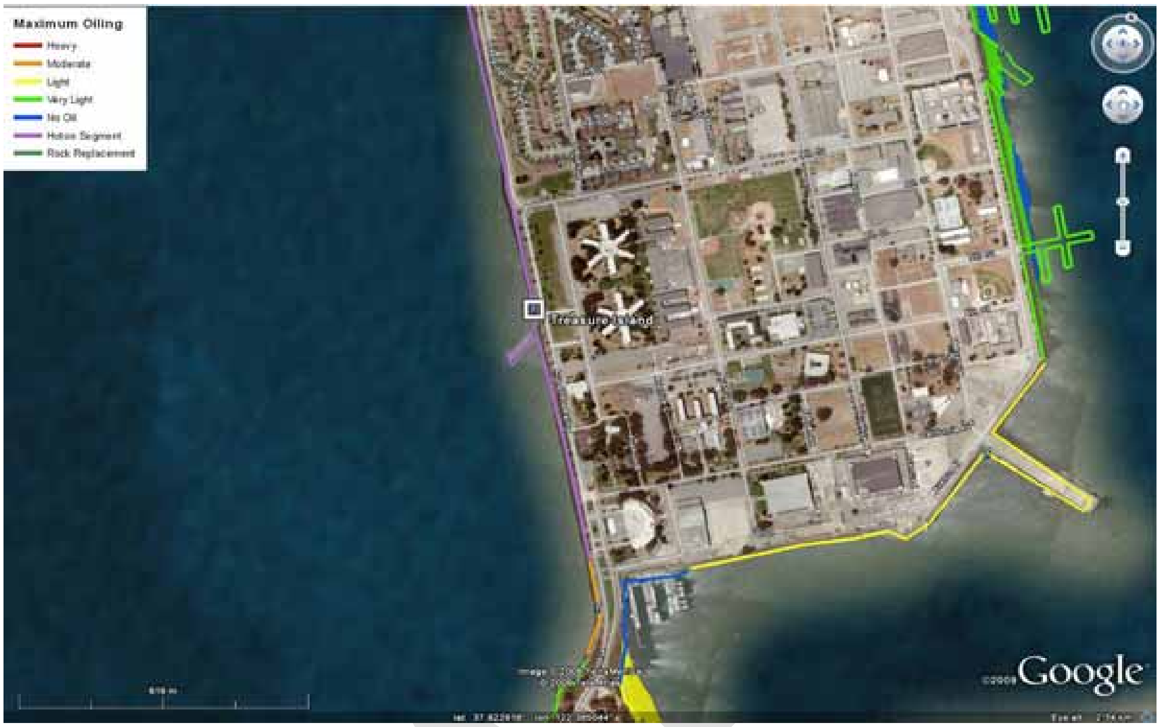


Figure 1-16: The site sampled at Treasure Island showing the level of oiling and the Hotsie Segment. The Hotsie segment is the area where power washing took place.

Figure 1-17: The site sampled at Yerba Buena Island showing the level of oiling.

Appendix 2: Site overview comparisons

Point Blunt


Figure 2-1: Point Blunt on 11-20-2007

Figure 2-2: Point Blunt on 11-20-2007

Figure 2-3: Point Blunt on 11-25-2007; photograph by Dennis Lees

Figure 2-4: Point Blunt on 11-25-2007; photograph by Dennis Lees

Figure 2-5: Point Blunt on 11-25-2007; photograph by Dennis Lees

Figure 2-6: Point Blunt on 02-05-2009 during the Tier II study.

Figure 2-7: Point Blunt on 02-05-2009 during the Tier II study.

Figure 2-8: Point Blunt on 02-05-2009 during the Tier II study.


Figure 2-9: Point Blunt on 02-05-2009 during the Tier II study.


Figure 2-10: Point Blunt on 02-05-2009 during the Tier II study.

Figure 2-11: Quadrat photos taken on 02-05-2009 at Point Blunt off of a 30m baseline transect (along the bottom). Sampling transects were run out every 3m from the baseline transect to the waters edge. Photos were taken every 3m along the sampling transects from the high zone (bottom of the photo) to the low zone (top of the photo). The horizontal numbers are distances in meters along the baseline transect at which the sampling transect was run out. The vertical numbers are distances in meters from the baseline transect where the photos were taken. This photo is meant to give a general overview of the community present at Point Blunt during the 2009 Tier II study.

Figure 2-12: Point Blunt, photo A was taken during the spill on 11-20-2007 and photo B was taken on 02-05-2009 during the Tier II study.

Figure 2-13: Point Blunt, photos A and B were taken during the spill on 11-25-2007 (photographs by Dennis Lees). Photos C and D were taken on
02-05-2009 during the Tier II study.

Berkeley Marina East

Figure 2-14: Photos A and B were taken 07-10-2006, before the spill. They were taken about 200m east of the Berkeley Marina East site. This area was lightly oiled and was not power washed. Photos C and D are from the Berkeley Marina East site. They were taken on 02-05-2009 during the Tier II study. This site was moderately oiled and was power washed.

Figure 2-15: Shows the area where the 2007 photos were taken with respect to the Berkeley Marina East site.