Determination of the extent and type of injury to rocky intertidal algae and animals during and after the initial spill (Dubai Star): a report prepared for California Department of Fish and Game Office of Spill Prevention and Response (DFG-OSPR)

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General Objectives

DETERMINE EXTENT AND TYPE OF INJURY TO ROCKY INTERTIDAL ALGAE AND ANIMALS DURING AND AFTER THE INITIAL SPILL

1. Was there a significant difference in the cover of dominant algal and invertebrate taxa between in-Bay rock riprap sites at various degrees of shoreline oiling?
2. Was there evidence for an "oiling" effect based on the comparison of impact and control sites over time?

Structure of the Report

This report is divided into two sections: Assessment and Appendix 1. 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 Dubai Star Oil Spill (which occurred on October 30th, 2009) on rocky intertidal communities that were affected by the spill. In Appendix 1 we present the characteristics of the sites assessed in Section 1.

Assessment - Methods

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 and low. Our surveys were designed to sample the areas so that all three zones were evaluated (tides permitting). Our transects were parallel to the shore and positioned in each of the three zones (low, mid, high), where possible (see additional explanation of methods below).

Sampling Methods

To determine the extent and type of injury to rocky intertidal algae and benthic invertebrates within the bay after the Dubai Star oil spill eight sites were sampled, seven of which were oiled prior to sampling. Three sites (two oiled and one not oiled) were then resampled in May and December of 2010 (Table 1).

Sampling transects were run parallel to the shoreline in the rocky intertidal at all sites sampled (Figure 1). Generally 3, 50 meter transects were sampled at a site, one to represent the high zone, one for the mid zone and one for the low zone. These zones corresponded to the upper limits of intertidal species zonation, the mid-zone and species associated with lower limit of rocky intertidal species at the sites. Each of these sampling transects branched off of a baseline transect that ran from a fixed landmark to the water's edge.

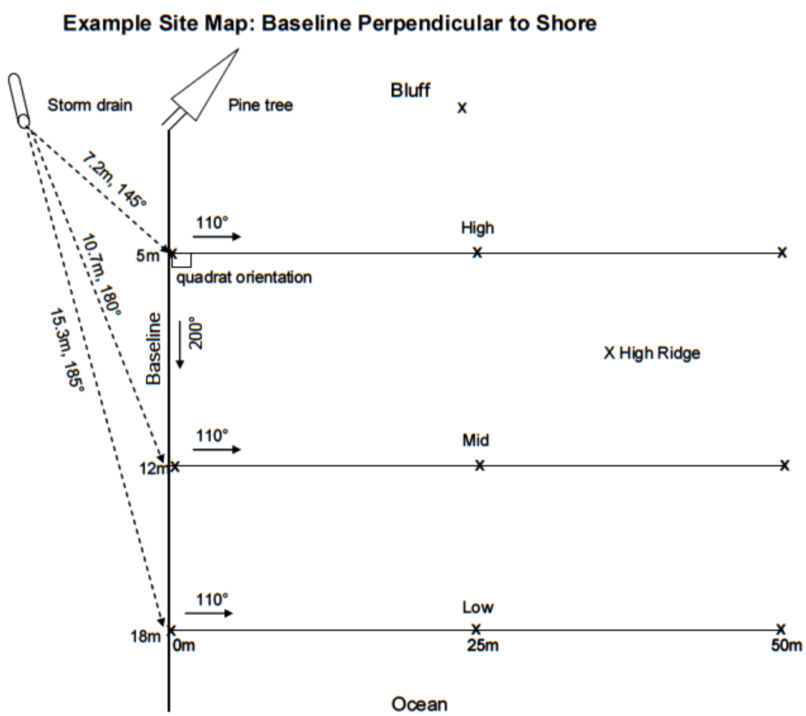


Figure 1: General layout of transects showing lines parallel to shore and indicating use of landmarks so as to ease relocation of transects.

Photographs, bearings and GPS coordinates were recorded for all transects so that they could be relocated and sampled again in the future. If conditions, tide or light did not allow for three transects to be completed, then one or two transects were done (see Table 2). High resolution photos (using 50 cm by 75 cm quadrat frames to standardize sampling) were taken every 5 meters along each transect starting at the 0 meter mark such that 11 photos were taken per transect. For each photoplot, a set of notes was taken that described the species in the plot and their location. These notes were used in subsequent sampling in the lab when the identity of a species was uncertain. In the lab each photo was projected on a computer screen and overlaid with a grid of 100 points. The species under each point was entered in a database and used to calculate the percent cover of sessile species within photoplots. Motile invertebrate species were also identified and counted within identically sized quadrats along each transect. These plots were sampled at 10 meter intervals along the transect using a 1 meter offset from the photoplots to avoid disturbing the plots (which may need to be subsequently re-sampled). In the mobile plots rocks were turned over to count crabs and snails, which often are not exposed. Shoreline Assessment Forms were filled out at each site sampled.

Segment ID	Site Name	Coordinates	Date Initially Sampled	Subsequent Sampling	Oiled prior to sampling	Oil band width (m)
ALD 01 Upcoast	Alameda Point Upcoast	N37.7881111˚ W122.3313056˚	10/31/2009		Yes	1
ALD 01 Downcoast	Alameda Point Downcoast	N37.7789167˚ W122.3175000˚	10/31/2009		Yes	0
ALD 02 Upcoast	Ballena Bay Upcoast	N37.766936˚ W122.288721˚	11/14/2009	5/01/2010 12/19/2011	Yes	10
ALD 02 Downcoast	Ballena Bay Downcoast	N37.764369˚ W122.285536˚	11/14/2009	5/01/2010 12/19/2011	Yes	10
ALD 12	Harbor Bay Island	N37.7451167˚ W122.2576667˚	10/31/2009		Yes	3.5
ALE 02 Upcoast	Oakland Airport Upcoast	N37.72243˚ W122.24883˚	11/01/2009		Yes	0.5
ALE 02 Downcoast	Oakland Airport Downcoast	N37.71594˚ W122.23949˚	11/11/2009		Yes	0.5
ALE 04	San Leandro Marina	N37.6982333˚ W122.1941000˚	11/30/2009	5/01/2010 12/19/2011	No	0

Table 1: Sites sampled. Coordinates are in decimal degrees. ALD01 was shown as having been oiled by SCAT surveys but no oiled width was detected.

Segment ID	Site Name	Transect Length	Zones	Sampling Done	n Photos	n Mobiles	Resampled
ALD 01 Upcoast	Alameda Point Upcoast	50m	High/Mid	Mobile / Photoplot	22	22	No
ALD 01 Downcoast	Alameda Point Downcoast	50m	High	Mobile / Photoplot	11	10	No
ALD 02 Upcoast	Ballena Bay Upcoast	50m	High/Mid/ Low	Mobile / Photoplot	33	15	Yes
ALD 02 Downcoast	Ballena Bay Downcoast	50m	High/Mid/ Low	Mobile / Photoplot	33	15	Yes
ALD 12	Harbor Bay Island	50m	High/Mid/ Low	Mobile / Photoplot	33	15	No
ALE 02 Upcoast	Oakland Airport Upcoast	50m	High/Mid/ Low	Mobile / Photoplot	33	15	No
ALE 02 Downcoast	Oakland Airport Downcoast	50m	High/Mid/ Low	Mobile / Photoplot	33	15	No
ALE 04	San Leandro Marina	50m	High/Mid/ Low	Mobile / Photoplot	33	15	Yes

Table 2: Segment ID and Site name designates the site sampled. Transect length is the length of the sampled transects in meters. Zones designates the different zones represented by tidal heights within the intertidal that were sampled; High being the high zone, Mid being the middle zone, and Low being the low zone. Sampling done denotes what was done at each site (mobile invertebrate counts and photoplot photos). n Photos denotes the number of photoplots sampled at each site. n Mobiles denotes how many mobile plots were sampled at each site. Resampled denotes whether or not the site was resampled in May and December of 2010.

Analytical Approach

We used a community based approach to assess the potential for impacts related to the oil spill. As noted above we were interested in two separate questions. First, was there a detectable effect from oil exposure on biological communities immediately following the spill? Here we compared samples that were taken at the time of the spill. Because intertidal communities occur in zones and because we wanted to be able to detect differences (if they occurred) by zone, we conducted separate analyses for each zone. In addition we compared mobile and sessile (photoplot) data separately. Each site was characterized as having been oiled or not and the width of the oil band that was present following oiling was recorded. Because the degree of oiling was considered light to very light, based on Shoreline Cleanup Assessment Technique (SCAT) data, at all oiled sites, the width of the oil band was considered a proxy for the potential for biological impacts resulting from oiling.

The second question we addressed was whether a temporal lag between samples at the same site would allow a more sensitive assessment of oiling than among sites sampled at the same time. Here the idea was to compare communities sampled soon after the spill (October 2009) and months after the spill (May and December 2010) for sites that were oiled and also for control sites. The key pattern that was looked for was whether a difference occurred at the oiled site that did not occur at the control site. This could indicate either (1) a delayed or chronic effect of oiling or (2) an effect that was present at the time of the spill that diminished over time. Here we compared observations between an oiled and an unoiled site. ALD02 was selected because it was considered the most heavily oiled of all the sampled sites, and was compared to an unoiled, control site, ALE04. The approach taken for the temporal analysis was somewhat different than that used for the analyses that made use of spatial comparisons on sampling done just after oiling. First, while we used all samples carried out in all zones, we did not separate the effects by zone. This was done because the results of the short-term sampling showed no effects that were stratified by zone. In addition the results showed that many of the species were present in multiple zones. Hence to capture the temporal effects we considered the site as the key spatial unit, rather than the zone. Second, for the temporal comparison we only had two sites, ALD02, which had been oiled and ALE04, which had not. Two segments of ALD02 and one of ALE02 were sampled in each of the three sample periods. For the purposes of the temporal analysis we considered the effects at the site, not segment, hence removing the possibility of spatial autocorrelation.

For both questions we relied on resemblance matrices developed using a Bray-Curtis approach (Primer E (ver.6) software package). Data were first transformed (square root) to diminish the effects of very abundant species. Resemblance matrices were then developed using a Bray-Curtis approach. These were the basis of subsequent analyses. For our first question whether there was a detectable effect of the spill on biological communities at the time of the spill, we compared biological similarity to similarity in oiling width using the RELATE function in PRIMER. This relates (using SPEARMAN rank probabilities) the Bray-Curtis similarity matrix for the biological variables to a matrix of the same configuration based on Euclidean distances for the estimated width of the oil band. Essentially this provides a method for comparing effects of the oil spill across the oiling gradient. For the second question, whether a temporal lag between samples at a given site would allow a more sensitive assessment of oiling effect, we used the PERMANOVA function in PRIMER. This is a permutation based community

ANOVA, which allows an examination of the interaction between sampling period and site, which is the key indicator of the possibility of an impact due to oiling, although other potential explanations were considered.

Assessment Results

Question 1: was there a detectable effect of the spill on biological communities at the time of the spill.

Photoplot data (sessile species) – There was no evidence that oiling had an immediate effect on the sessile community at any tidal level. The relationship between extent of oiling and biological community was strongly non-significant (P>0.30) for all comparisons (High: P=0.336, Mid: P=0.543, Low: P=0.526). Figure 2 is a graphical depiction of these results. The key visual attribute of the figure is that the pattern of community composition is not reflected in the pattern of oiling.

Mobile species – Here there was some indication that the mobile community differed as a function of either oil width at the site or with the site itself (Figure 3, Table 3). The relationship between extent of oiling and biological community was significant at the P<0.10 for all comparisons (High: P=0.052, Mid: P=0.068, Low: P=0.068). Across all zones there were 7 relationships that were positive and 2 that were negative. There are two reasonable possibilities for these positive results: (1) the effects are driven by site differences, and were not influenced by oiling effects, or (2) oiling caused some species to emerge from refuges and hence be more likely to be counted.

	Probability					
	Zone					
Species	**Low**	**direction**	**Mid**	**direction**	**High**	**direction**
LARGE LIMPETS	0.205		0.018	+	0.014	+
MEDIUM LIMPETS	0.431		0.486		0.421	
SMALL LIMPETS			0.787		0.003	+
TEGULA FUNEBRALIS			0.107		0.242	
PAGURUS					0.769	
PACHYGRAPSUS			0.407			
HEMIGRAPSUS	0.020	+	0.000	+	0.007	+
CANCER	0.004	+	0.511			
DEAD CANCER	0.472					
LITTORINA			0.115		0.292	
LEPIDOCHITONA DENTIENS			0.558		0.246	
LEPIDOCHITONA HARTWEGII						
IDOTEA					0.242	
LIGIA			0.311		0.609	
AMPHISSA	0.478		0.972		0.626	
SEARLESIA	0.022	-	0.079	-	0.242	

Table 3: Relationships between mobile species and width of oil band. Probability values are shown in column under zone (low, mid, high). If the p-value was significant ($p<0.10$), then the direction of the relationship is indicated in direction column to the right.

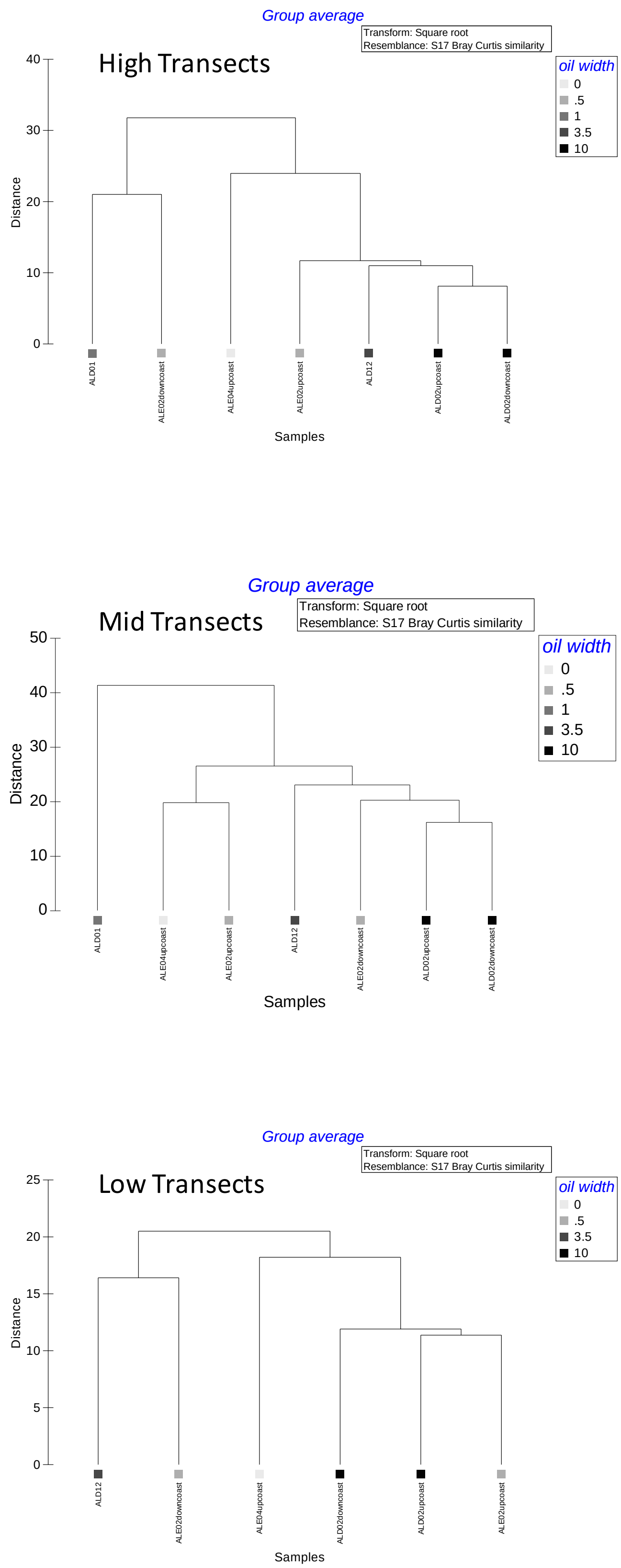


Figure 2: Oiling and community similarity in photoplots (sessile species).

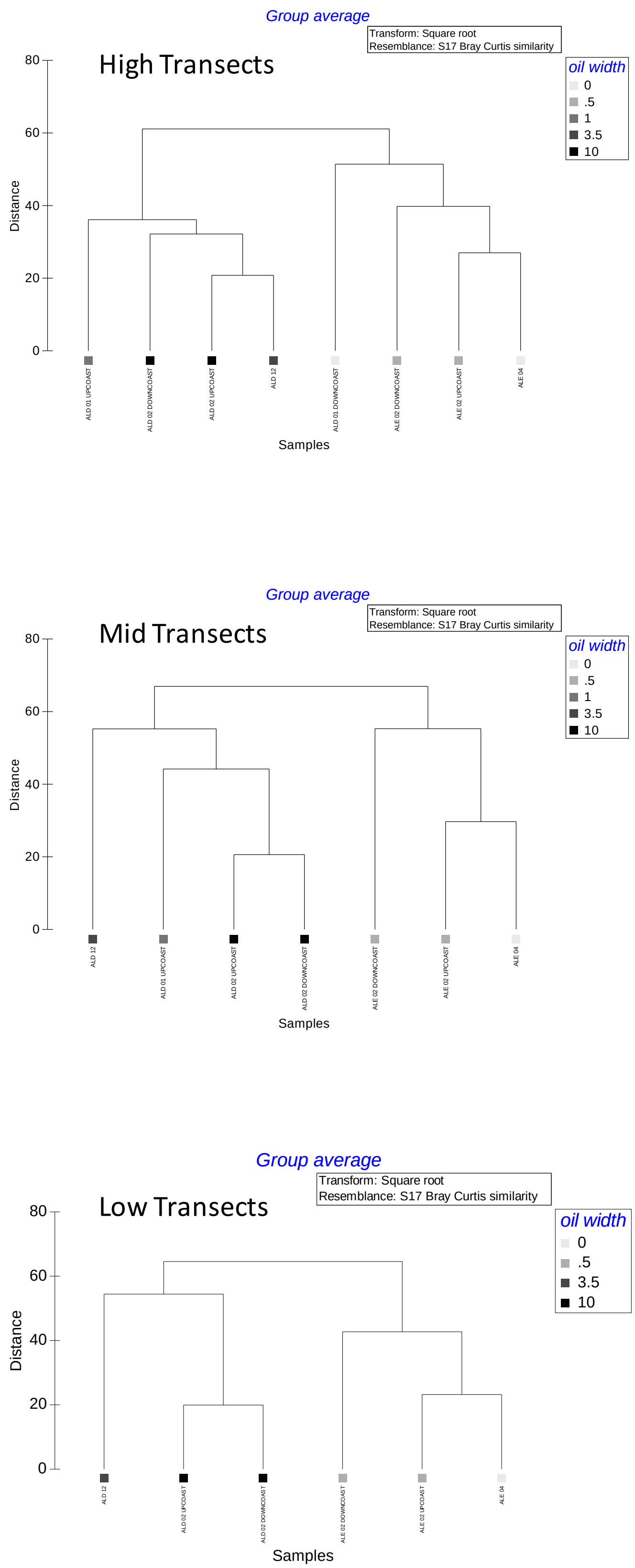


Figure 3: Oiling and community similarity for mobile species.

Question 2: Was there evidence of an "oiling" effect based on the comparison of impact and control sites over time?

As noted the relationship of interest is the interaction between site and sample period. Such an interaction could result in a number of ways. However, one pattern that would suggest the possibility of an impact due to oiling would be if the communities at the oiled site were more different between periods than the same comparison for the control (non-oiled) sites.

Photoplot data (sessile species) – There was a strongly significant interaction (P=0.001) between site and sample period (Table 4, Figure 4). Three species exhibited changes that may have been a result of oiling effects. First, soon after the oiling event barnacles, (*Chthamalus and Balanus*) were lower at the oiled site than at the control site. Over time the abundance at the oiled site increased and that at the control site decreased such that by period 3 they were similar. Second, the green algae, *Ulva*, a species that is very opportunistic, was much higher in the oiled site in period 1, and over time converged back to approximate levels found at the control site. Finally, *Fucus,* a longer lived species than either the barnacles or *Ulva,* started at the same level at both sites. By period 2, it had increased at the control site, without a similar increase at the oiled site. By period 3, *Fucus* had increased at the oiled site and was more abundant (not significantly) at the oiled site than at the control site. All of these patterns are similar to those found during the Cosco Busan spill (see *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*). This similarity and the relationship between the pattern and life history of the species suggest a short term (~1 year) impact due to the spill.

Mobile species – There was a strongly significant interaction between site and sample period (Table 5, Figure 5). Three of the six species (the crab, *Hemigrapsus*, and two snails, littorines and *Tegula*) showed a remarkably similar pattern: abundance at the oiled site was similar to the control sites for the first and second period and then became much more abundant at the oiled site, during the third period. This pattern is consistent with a relatively short-term effect of oiling on abundance or behavior of these species. That is, these species were generally more abundant at the oiled site but were temporarily suppressed by the effects of oiling. It is also consistent with other more geographic effects. The temporal patterns associated with three other species seem more likely to be the result of geographic effects rather than oiling.

PERMANOVA table of results						
						Unique
Source	df	SS	MS	Pseudo-F	P(perm)	perms
Site	1	23885	23885	25.738	0.001	999
Period	2	14140	7070.2	7.6188	0.001	999
SitexPeriod	2	11697	5848.3	6.3021	0.001	999
Residual	290	2.69E+05	927.99			
Total	295	3.26E+05				

Table 4: PERMANOVA results for the comparison of biological communities (photoplot data) as a function of sample period (during, May 2010 and December 2010) and site (oiled vs non-oiled). Note the presence of significant interaction for all tidal heights. Also see Figure 4

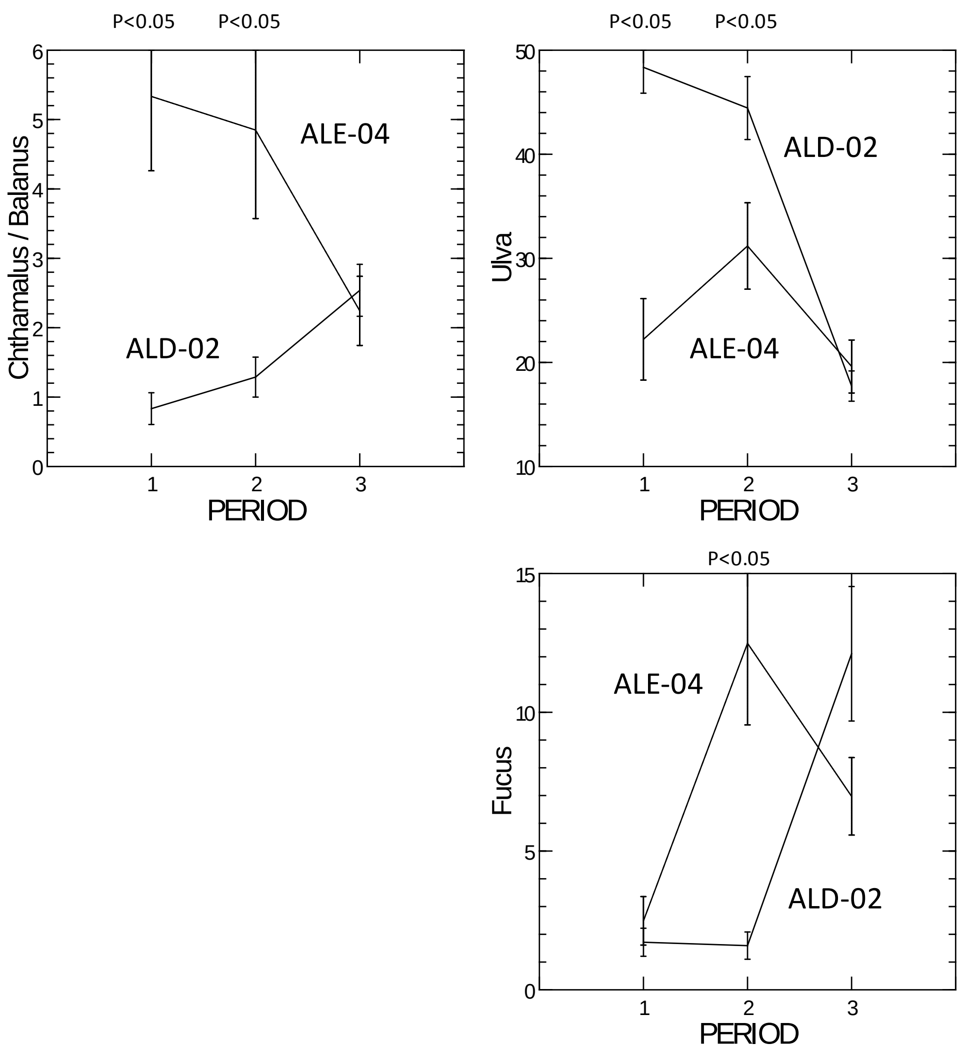


Figure 4: Comparison of sessile species (photoplot data) as a function of sample period (1= during, 2= May 2010, 3=December 2010) and site (oiled = ALD-02 vs non-oiled =ALE-04). P-values indicate differences between sites for the period. Values are the percent cover of the target species. Also see Table 4. Species shown are those most consistent with interaction effect in Table 4. Standard Errors are shown with means.

PERMANOVA table of results						
						Unique
Source	df	SS	MS	Pseudo-F	P(perm)	perms
Site	1	87443	87443	38.543	0.001	999
Period	2	21235	10618	4.68	0.001	998
SitexPeriod	2	11566	5782.9	2.549	0.011	999
Residual	151	3.43E+05	2268.7			
Total	156	4.68E+05				

Table 5: PERMANOVA results for the comparison of biological communities (mobile species) as a function of sample period (during, May 2010 and December 2010) and site (oiled vs non-oiled). Note the presence of significant interaction for all tidal heights. Also see Figure 5.

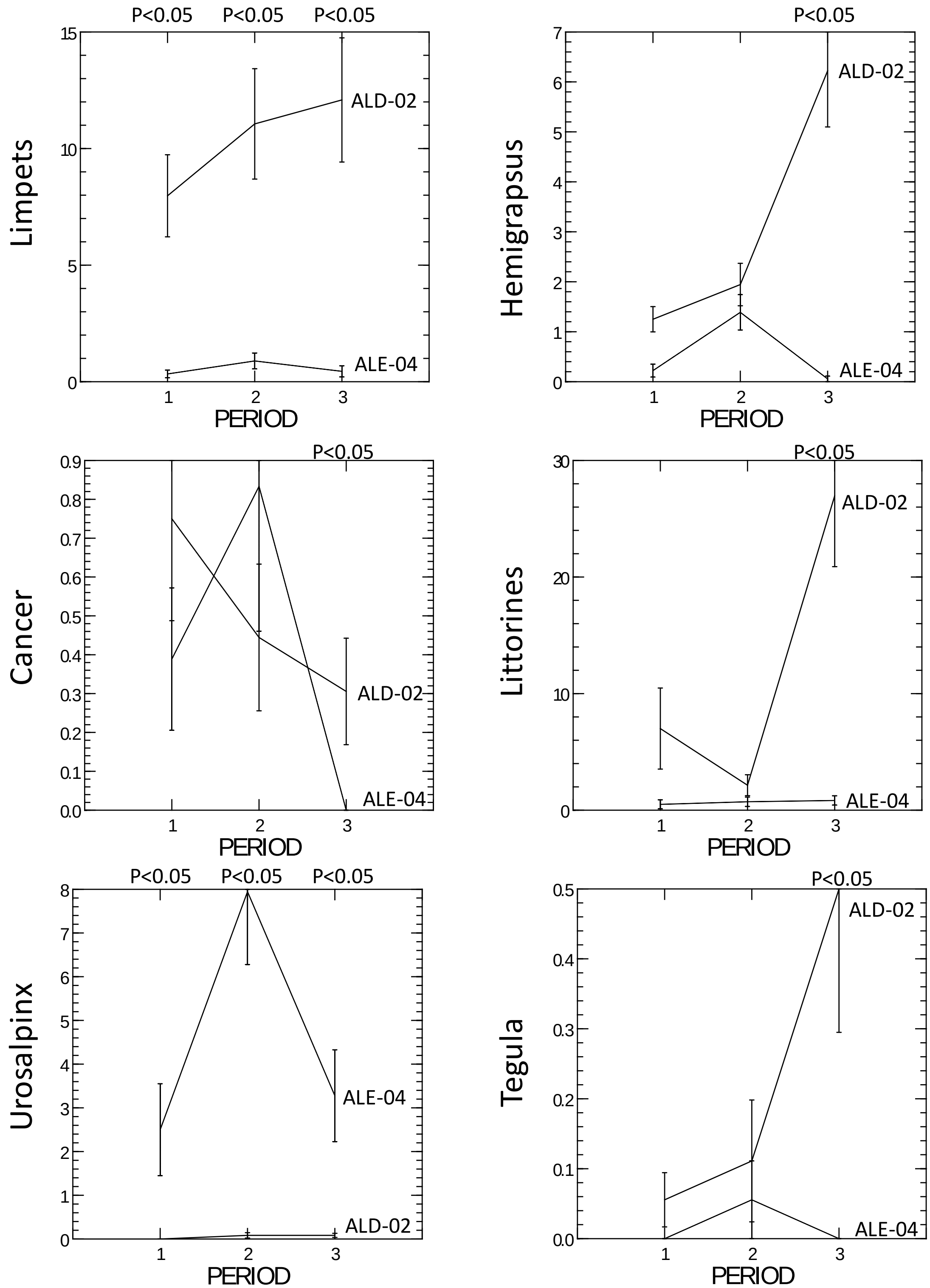


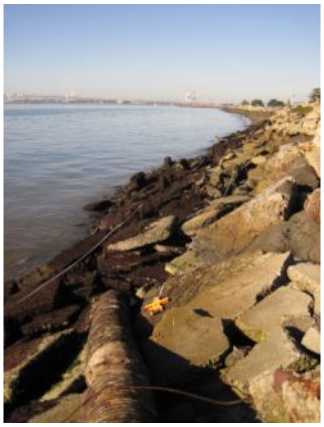
Figure 5: Comparison of mobile species as a function of sample period (1= during, 2= May 2010, 3=December 2010) and site (oiled = ALD02 vs non-oiled =ALE04). Values are the number of organisms per quadrate (50 x 75 cm). P-values indicate differences between sites for the period. Also see Table 5. Species shown are those most consistent with interaction effect in Table 5. Standard Errors are shown with means.

General Summary

The results of the analyses described above indicate that species composition for sessile organisms could not be definitively associated with oiling level during or very near to the time of the spill. By contrast, there was evidence that mobile species composition did vary with oiling level for the same time period. Although an impact on behavior due to oiling could explain the pattern, it may also reflect differences among sites. The spatial variability evident across sites at a single time points to the importance of assessing the pattern of change over time within individual sites.

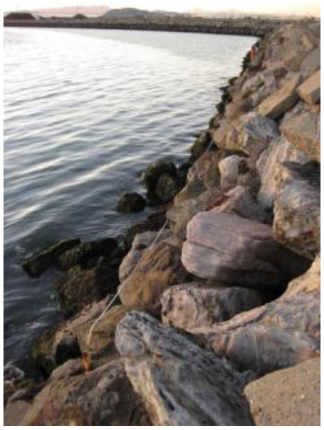
The second set of analyses was designed to assess whether the signal of oiling could be detected by looking at the change in species composition over time at oiled and control sites. As noted above, the differences in temporal patterns between oiled and control sites for both mobile and sessile species could indicate effects due to oiling. This pattern was found for both mobile and sessile species. Again, there are explanations other than an impact due to oiling; however, the changes in specific species driving the overall community association were consistent with potential oiling effects. The temporal patterns are consistent with impacts due to oiling and are similar to those observed following the Cosco Busan oil spill. Other potential, but less likely, explanations cannot be excluded without further research.

Appendix 1: Site Characteristics



Alameda Point Upcoast

Alameda Point Upcoast (SCAT segment ALD 01 upcoast) is located at 37.788111˚ N and 122.3313056˚ W. The primary substrate at this site is riprap. The site was oiled before sampling took place on 10-31-2009. There was a low tide of 0.3 feet at 5:24pm and sampling was carried out from 3:05 pm to 7 pm. The surface oiling conditions were reported as being sporadic (1-10% cover), 100 meters long and 3 meters wide with fresh pooled oil. The sampling transects were 50 meters long in the high and mid zones of the intertidal. Eleven 50 cm x 75 cm photoplots were photographed along each transect (22 total photographs) and photo notes were taken. Each photo was then sampled for 100 points back at the laboratory. Eleven motile invertebrate counts along each transect (22 total) were taken in 50 cm x 50 cm quadrats. This site was not resampled.



Alameda Point Downcoast

Alameda Point Downcoast (SCAT segment ALD 01 downcoast) is located at 37.7789167˚ N and 122.3175000˚ W. The primary substrate at this site is riprap. The site was oiled before sampling took place on 10-31-2009. There was a low tide of 0.3 feet at 5:24 pm and the sampling time for this site is included above. The surface oiling conditions were reported as being sporadic (1-10% cover), 100 meters long and 3 meters wide with fresh pooled oil. The sampling transects were 50 meters long in the high zone of the intertidal. Eleven 50 cm x 75 cm photoplots were photographed along the transect and photo notes were taken. Each photo was then sampled for 100 points back at the laboratory. Ten motile invertebrate counts along the transect were taken in 50 cm x 50 cm quadrats. Only the high zone was sampled at this site because of time constraints with nightfall. This site was not resampled.

Ballena Bay Upcoast

Ballena Bay Upcoast (SCAT segment ALD 02 upcoast) is located at 37.766936˚ N and 122.288721˚ W. The primary substrate at this site is man made large cobble. The site was oiled before sampling took place on 11-14-2009. There was a -0.5 foot low tide at 4:24 pm and sampling was carried out between 2:15 pm and 4:15 pm. The surface oiling conditions were reported for two zones (high and supra intertidal). The supra intertidal (above the normal high tide level) was reported as being brokenly oiled (60% cover), 500 meters long and 2 centimeters wide with a coat (visible oil which can be scraped off with fingernail) of fresh oil. The high intertidal was reported as having trace oil (< 1%) 500 meters long and 2 meters wide characterized as coated with tarballs present. The sampling transects were 50 meters long in the high, mid and low zones of the intertidal. Eleven 50 cm x 75 cm photoplots were photographed along each transect (33 total photographs) and photo notes were taken. Each photo was then sampled for 100 points back at the laboratory. Five motile invertebrate counts along each transect (15 total) were taken in 50 cm x 75 cm quadrats. This site was resampled on 05-01-2010 and 12-19-2010. All of the above sampling was repeated.

Ballena Bay Downcoast

Ballena Bay Downcoast (SCAT segment ALD 02 downcoast) is located at 37.764369˚ N and 122.285536˚ W. The primary substrate at this site is man made large cobble. The site was oiled before sampling took place on 11-14-2009. There was a -0.5 foot low tide at 4:24 pm and the sampling time for this site was included above. The surface oiling conditions were reported for two zones (high and supra intertidal). The supra intertidal (above the normal high tide level) was reported as having patchy oil (20% cover), 500 meters long and 2 centimeters wide with a coat (visible oil which can be scraped off with fingernail) of fresh oil. The high intertidal was reported as having trace oil (< 1%) 500 meters long and 2 meters wide characterized as coated with tarballs present. The sampling transects were 50 meters long in the high, mid and low zones of the intertidal. Eleven 50 cm x 75 cm photoplots were photographed along each transect (33 total photographs) and photo notes were taken. Each photo was then sampled for 100 points back at the laboratory. Five motile invertebrate counts along each transect (15 total) were taken in 50 cm x 75 cm quadrats. This site was resampled on 05-01-2010 and on 12-19-2010. All of the above sampling was repeated.

Harbor Bay Island

Harbor Bay Island (SCAT segment ALD 12) is located at 37.7451167˚ N and 122.2596667˚ W. The primary substrate at this site is riprap. The site was oiled before sampling took place on 10-31-2009. There was a 0.3 foot low tide at 5:24 pm and sampling was carried out between 2:40 pm and 5:49 pm. The surface oiling conditions were reported as being trace oil with a thickness ranging from coat to cover (0.1 - 1 cm) with tarballs in the high intertidal. The two SCAT sub-segments in ALD 12 had an average oil band width of 3.5 m and a total length of 1393 m. The sampling transects were 50 meters long in the high, mid and low zones of the intertidal. Eleven 50 cm x 75 cm photoplots were photographed along each transect (33 total photographs) and photo notes were taken. Each photo was then sampled for 100 points back at the laboratory. Five motile invertebrate counts along each transect (15 total) were taken in 50 cm x 75 cm quadrats. This site was not resampled.

Oakland Airport Upcoast

Oakland Airport Upcoast (SCAT segment ALE 02 upcoast) is located at 37.72243˚ N and 122.24883˚ W. The primary substrate at this site is riprap. The site was oiled before sampling took place on 11-01-2009. There was a -0.2 foot low tide at 4:59 pm and sampling was carried out between 1:30 pm and 5:30 pm. The surface oiling conditions were reported as being sporadic pooled oil in the form of tarballs within a 3-meter wide oil band approximately 3.2 kilometers long. The sampling transects were 50 meters long in the high, mid and low zones of the intertidal. Eleven 50 cm x 75 cm photoplots were photographed along each transect (33 total photographs) and photo notes were taken. Each photo was then sampled for 100 points back at the laboratory. Five motile invertebrate counts along each transect (15 total) were taken in 50 cm x 75 cm quadrats. This site was not resampled.

Oakland Airport Downcoast

Oakland Airport Downcoast (SCAT segment ALE 02 downcoast) is located at 37.71594˚ N and 122.23949˚ W. The primary substrate at this site is riprap. The site was oiled before sampling took place on 11-11-2009. There was a -0.2 foot low tide at 4:59 pm and the sampling time was included above. The surface oiling conditions were included in the above (Upcoast) report. The sampling transects were 50 meters long in the high, mid and low zones of the intertidal. Eleven 50 cm x 75 cm photoplots were photographed along each transect (33 total photographs), because of time constraints, no photo notes were taken. Each photo was then sampled for 100 points back at the lab. Five motile invertebrate counts along each transect (15 total) were taken in 50 cm x 75 cm quadrats. This site was not resampled.

San Leandro Marina

San Leandro Marina (SCAT segment ALE 04) is located at 37.6982333˚ N and 122.1941000˚ W. The primary substrate at this site is riprap. The site was not oiled before sampling took place on 11-30-2009. There was a -0.8 foot low tide at 4:39 pm and sampling was carried out between 12:30 pm and 4:45 pm. The sampling transects were 50 meters long in the high, mid and low zones of the intertidal. Eleven 50cm x 75cm photoplots were photographed along each transect (33 total photographs). Because of time constraints, no photo notes were taken during the first survey. Each photo was then sampled for 100 points back at the laboratory. Five motile invertebrate counts along each transect (15 total) were taken in 50 cm x 75 cm quadrats. This site was never oiled and was resampled on 05-01-2010 and on 12-19-2010. All of the above sampling was repeated.

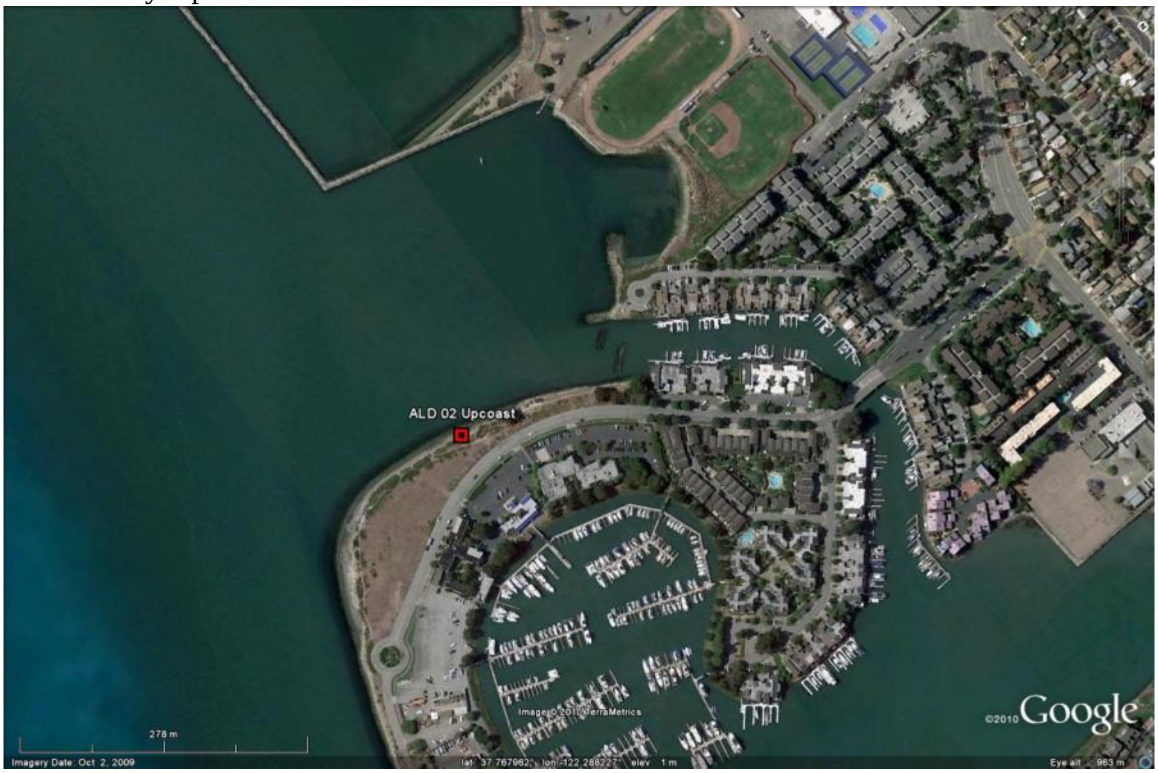
Maps of Sites

All sites

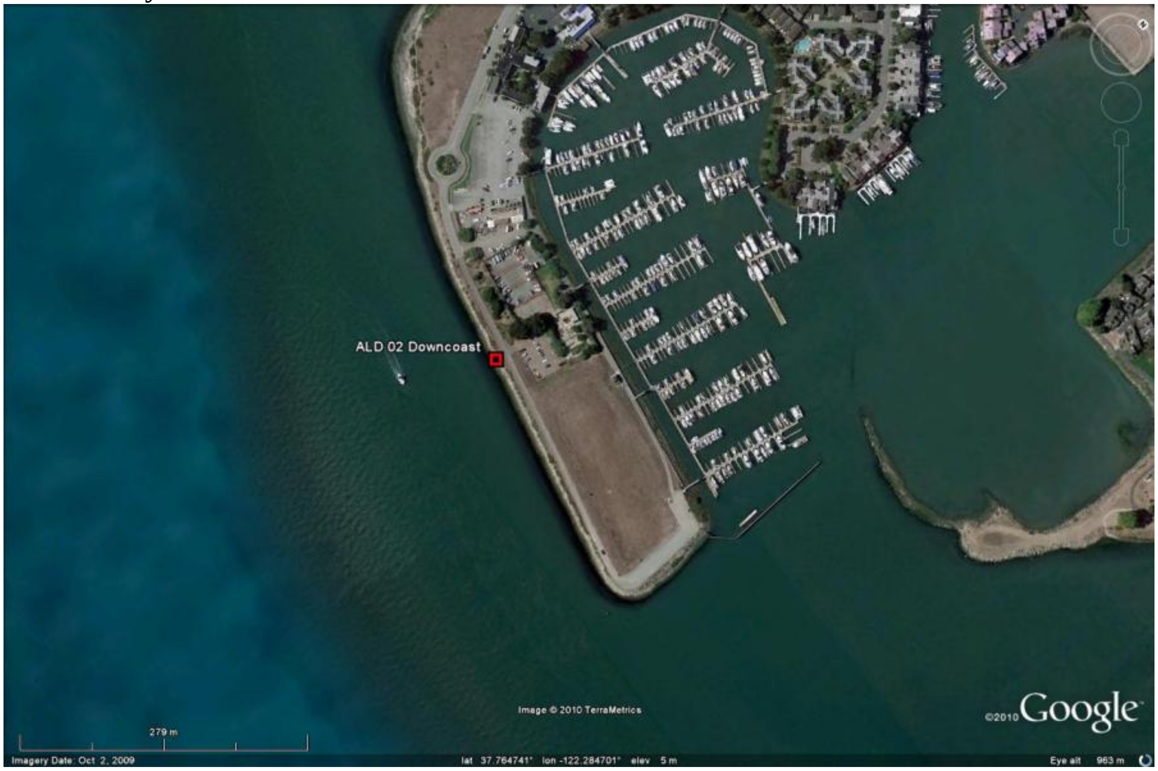
Alameda Point Upcoast

Alameda Point Downcoast

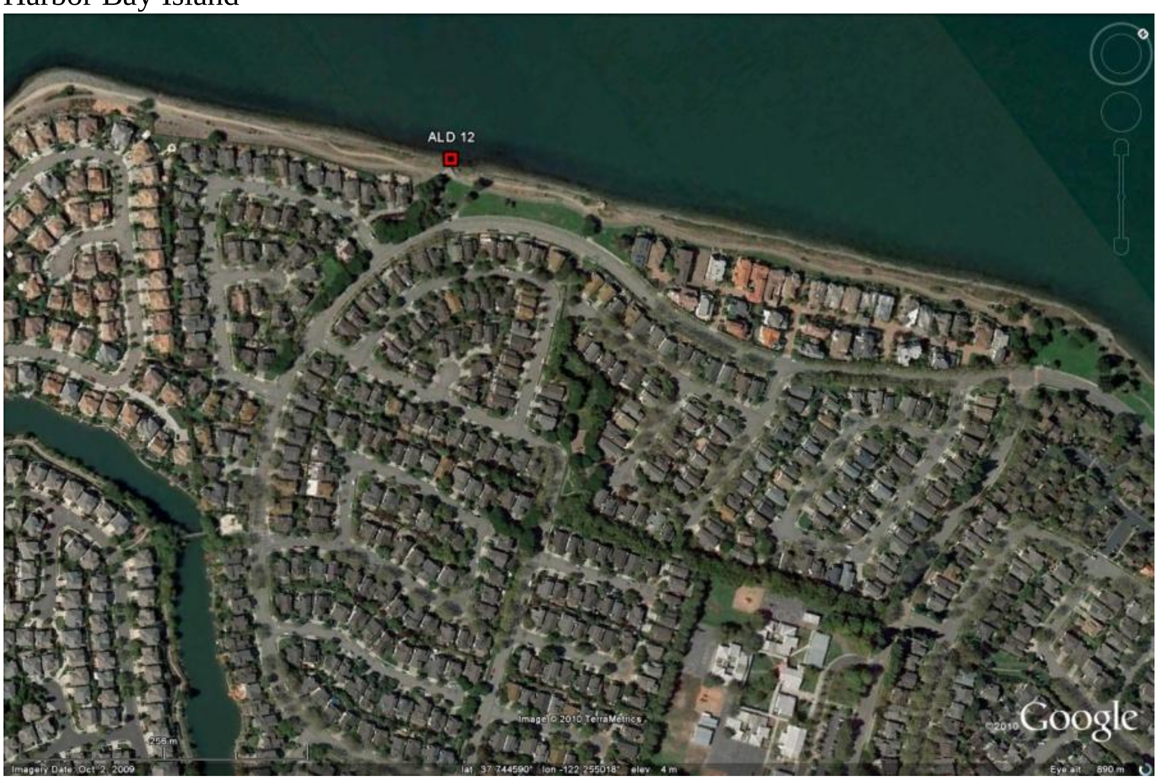
Ballena Bay Upcoast



Ballena Bay Downcoast

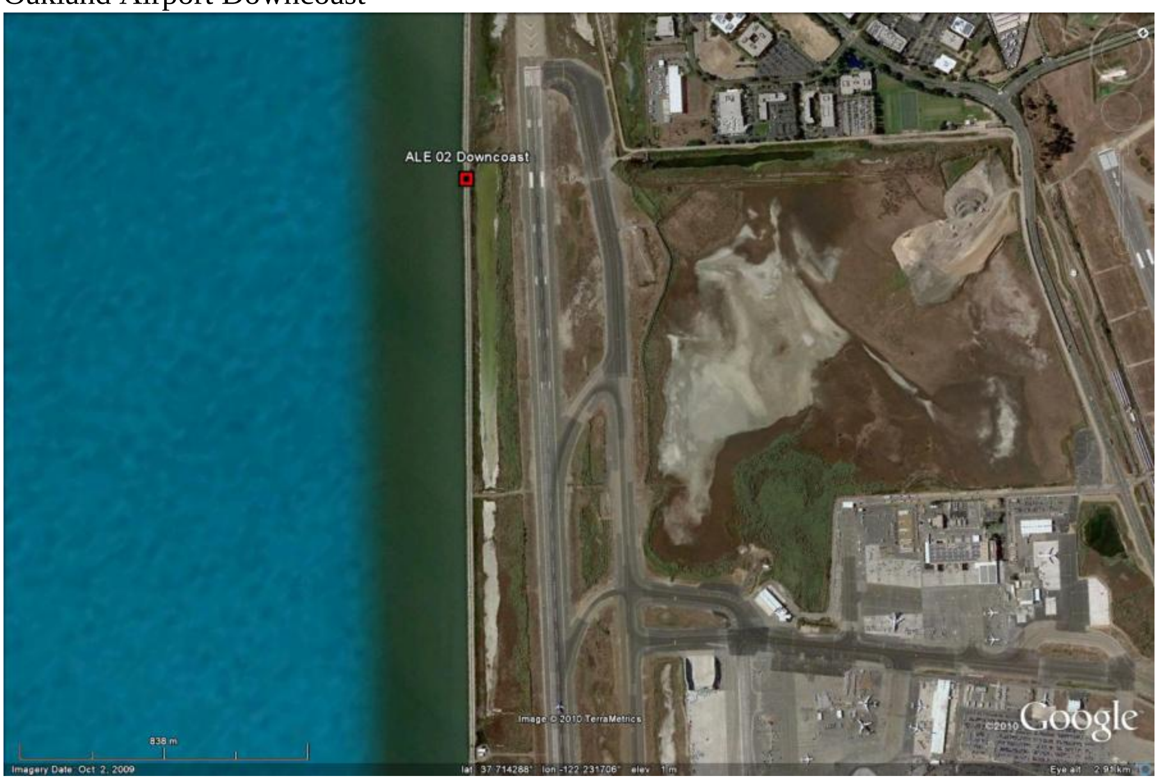


Harbor Bay Island



Oakland Airport Upcoast

Oakland Airport Downcoast



San Leandro Marina